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THE EGYPTIAN SPECIES OF THE GENUS *BEMBYX* F.

[*Hymenoptera* : *Sphecidae*]

(with 19 Illustrations)

by Prof. Dr. H. PRIESNER

The difficulties I encountred in the identification of the Egyptian forms of the genus *Bembyx* necessitated a closer study of this group.

HONORÉ (1942) listed in his outline of the *Sphecidae* of Egypt the following species as Egyptian : *chlorotica* Spin., *lusca* Spin., *fischeri* Spin., *dahlbomi* Hdl., *mediterranea* Hdl., *oculata* Latr., *kohli* Mor., and *frey-gessneri* Mor., but mentions localities only for *lusca* (Hawamdiah, Gebel Asfar), *dahlbomi* (Kosseir) and *kohli* (Dahshour).

After a thorough study of the Egyptian species it appeared that there exist, besides those recorded by HONORÉ, about the same number again of other species, partly new to this country, and partly new to science.

The excellent monograph of the genus by HANDLIRSCH (1893) enabled me to confirm the presence in this country of the species *turca* Ol., *fischeri* Hdl. = *doriae* Magr., *chlorotica* Spin., *dahlbomi* Hdl., *olivacea* F. (*mediterranea* Hdl.), *oculata* Latr., and *lusca* Spin., *Bembyx frey-gessneri* Mor. and *kohli* Mor., described from Egypt, were also confirmed. Of *Bembyx fischeri* Hdl. (nec Spin.), the male was found so that this species could be referred to the group where it belonged (sc. *fuscipennis*), while Dr. DE BEAUMONT identified the true *fischeri* Spin. by comparison of my description with the type.

As new to Egypt have to be recorded: *Bembyx chopardi* Berl., *melanura* Rad., *palaestinensis* Lohrm., *turca picturata* BytS. and *radoszkowskyi* Hdl. As new to science the species *abragensis*, *alfierii*, *nilotica*, *pallescens* and *rufiventris* are described below.

Some remarks have to be made with regard to the comparative morphology of the species. Although it is common knowledge that the coloration of the body and its appendages varies considerably, it is inspite of this variability rather important

for the separation of the species, particularly for the female sex, if one pays attention to the position of the markings or combinations of them, especially on the abdomen and the legs. The markings on the legs were hitherto treated just summarily, but I noticed that some species show a dark line on the *inside* of the middle and hind tibiae, while in others the *posterior* face of the tibiae is lined with black, and in other species again both, the interior as well as the posterior darkenings, are developed, and there are species in which the tibiae seem to be always entirely yellow: on the femora the blackenings are shown on the posterior face, while in others the black stripe is constantly found on or near the upper (anterior) edge of the femur.

Then there are some more important structural characters which should be mentioned in the diagnoses of the groups, like the relative lengths of the basal antennal joints (1 and 3), and particularly the wing venation. HANDLIRSCH (l.c.) had already tried to make use of some differences in the development of the vein rudiments issuing from the large cell of the hind wing; as these are *small* rudiments of veins this character is often not reliable. However, there are other venational characters much more easily noticeable, namely firstly the cross-vein closing apically the posterior cell of the hind wing. This cross-vein is in most species slightly curved or straight, and about *vertical* to both longitudinal veins so that the angles formed with the latter are about equal (cf. *oculata*-group). In some species this cross-vein is oblique so that it forms with the second vein either an obtuse angle exteriorly below, as e.g. in *Bembyx chlorotica, palaestinensis, rufiventris* and *alfierii*, or a pointed angle, as e.g. in *olivacea, dahlbomi* and *lusca*. Naturally, the sexes agree in this respect.

In the fore wing, the shape of the vein Rt 1 (or 1st cubital vein) should also be mentioned as an important group character. This vein is scarcely curved in the species having finely and densely punctured sternites (e.g. *megerlei*-group a.o.), while it is strongly curved inward below in the species having coarsely and sparingly punctured sternites (e.g. *oculata*-group).

In many species the sexes are quite similar in their colour pattern (e.g. *oculata*, *lusca*, *turca*, etc.), in others, though, they differ considerably, and this is most obvious in *Bembyx frey-gessneri* and the species of the *megerlei*-group. As a rule, the males are somewhat darker than the females as to the markings of the body and the appendages.

With regard to the nomenclatorically valid name of the genus I wish to refer to DE BEAUMONT'S (1954) note on this subject, in which he follows PATE (1937) in preserving the name given by FABRICIUS. In this case, however, FABRICIUS' later spelling has, as to my opinion, to be used, i.e. *Bembyx*, and not *Bembix*.

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KEY TO THE EGYPTIAN SPECIES OF *BEMBYX*

1. Males

1 (2) Length 25 mm. Tergite VI truncate at the apex. Pale colour whitish-yellow ..... **fischeri Spin.**

2 (1) Length at most 20 mm.

3 (16) Antennal joint 12 posteriorly at least in one direction distinctly *convex*.

4 (5) Colour almost wholly black, the yellow design on the abdomen of pale specimens consisting at most of narrow, interrupted, yellow bands, or abdomen entirely black. Tibiae strongly blackened. Propodeum black.... ..... **turca Dhlb.**

5 (4) Abdomen with full yellow bands.

6 (7) Venter at least at base ferruginous. Metatarsus of mid leg with lobiform dilatation within. Mid femora without row of small teeth. Male genitalia as in Fig. 12 (Sinai, Red Sea coast) ..... **doriae Magr.**

7 (6) Not the above characters combined.

8 (9) Tergite VII at the sides with a fine transverse incision so that two teeth are formed. Antennal 3 much shorter than 1. Venter almost wholly yellow. Posterior cell of hind wing at the lower exterior angle somewhat pointed ..... **chopardi Berl.**

9 (8) Tergite VII without sharp horizontal incision. Antennal 3 at most slightly shorter than 1, often as long as it or longer.

10 (11) Body comparatively broad. Wings in most cases slightly shaded. Apical tergite with yellow spots. Propodeum black ..... **picturata Bytś.**

11 (10) Narrower species. Apical tergite black. Wings always hyaline.

12 (13) Platform of sternite VI not longitudinally furrowed, from tip to apex of abdomen carinated. On the propodeum are at most the hind angles yellow. Hind tibiae without, or posteriorly with, black line. Venter black, with yellow lateral spots. Antennal 1 little thickened..... **frey-gessneri Morice**

13 (12) Platform on sternite VI slightly furrowed at the apex, and the space between it and the hind margin of the segment without carina. Antennal 1 distinctly thickened.

14 (15) Mesosternum with two large black lateral spots. Mesonotum with yellow U-shaped spot. Antennal 1 orange beneath ..... **melanura Moraw.**

15 (14) Mesosternum black, with lateral yellow spots. Mesonotum black. Antennal 1 yellow beneath ..... **melanura Moraw. var.**

16 (3) Antennal joint 12 straight or more or less concave posteriorly.

17 (22) Metatarsus of mid leg flatly excavated within, with conspicuous bristles in front of the emargination. Mid tibiae curved.

18 (19) Venter yellow, with much reduced black markings. Smaller, richly yellow coloured species ..... **pallescens sp. n.**

19 (18) Venter black, with yellow lateral spots.

20 (21) Platform of sternite VI not dentate posteriorly, in lateral aspect. Antennal joint 10 angular within and excavated in distal half, in profile. All femora and at least the fore and middle tibiae lined with black, *posteriorly*. Tergites with poor yellow design ..... **kohli Morice**

21 (20) Platform of sternite VI with apical tooth, declivity concave in profile. The small elevation on antennal joint 10 not angular. Middle femora wholly yellow. Abdomen with full yellow cross bands ..... **nilotica sp. n.**

22 (17) Metatarsus of mid leg without conspicuous bristles at the interior margin, apical half (or more) with at most very short bristles.

23 (24) Fore and middle femora with row of fine teeth. Body colour pale greenish-yellow or greyish-yellow. Apical tergite excavated at the posterior margin ..... **dahlbomi Handl.**

24 (23) Fore femora without, only middle femora with, row of small teeth.

25 (30) Antennal joint 1 black.

26 (27) Second cell of hind wing pointed apically below, cross vein oblique. Sternite II without hump but with carina that is never pointed at the apex. Antennal joint 13 pointed at tip. Parameres black, pincer-shaped, i.e. truncate at the apex with sharp angles, and interior margin dentate. Labrum blackened in the middle, and also the metatarsus I beneath. Propodeum black. Puncturation of the thorax less dense ..... **lusca Spin.**

27 (26) Second cell of hind wing not pointed apically, its closing cross vein, though more or less curved, vertically posited. Sternite II with carinated hump, or in weak males, with a carina that is always pointed apically, in lateral aspect. Antennal 13 rounded at tip. Parameres more or less slender, narrowed towards tip, not dentate interiorly. Puncturation of thorax denser.

28 (29) Parameres more or less gradually narrowed towards apex, without slanting. Thorax, and particularly the propodeum, with yellow markings. Abdomen with full yellow cross fasciae. Femora black at base ..... **oculata Latr.**

29 (28) Parameres, though slender, with a strongly oblique slanting at the apex within (Fig.16). Thorax, propodeum and most of the abdomen black, the whitish-yellow transverse markings on segments (II-IV) much reduced and interrupted at middle. Femora for the major part black ..... **abragensis sp. n.**

30 (25) Antennal joint 1, at least beneath, yellow.
31 (36) Sternites III-V medially rather coarsely punctured or almost smooth.
32 (33) Venter along middle somewhat ferruginous. Antennal joint 3 longer than 1. Black lines on femora situated near fore margin. Pale colour yellow. Posterior cell of hind wing with lower apical angle obtuse .... **rufiventris sp. n.**
33 (32) Venter not ferruginous. Antennal 3 scarcely as long as 1 or somewhat shorter.
34 (35) Pale colour yellow. Sternite II with carinated tooth, VI with platform. Tergite VII simple. Cross vein of 2nd cell of hind wing vertical. Metatarsus II slightly emarginated at the middle within ..... **radoszkowskyi Handl.** (1)
35 (34) Pale colour greyish-yellow. Sternites without elevations. Tergite VII near base with a tooth on either side. Cross vein of hind wing oblique, 2nd cell therefore pointed at the lower apical angle ..... **olivacea saharae G.M.**
36 (31) Sternites III-V either very finely and densely punctured and shortly pubescent, or very finely and moderately densely punctured with black raised hairs. Posterior cell of hind wing obtusely angled.
37 (40) Fore tarsi slender, with black dots or minute black spines beneath.
38 (39) At least the fore tarsi with black dots beneath. Mesosternum black in the middle. Sternites III-V moderately densely punctured with black raised hairs. Parameres black, truncate at the apex ..... **chlorotica Spin.**
39 (38) Joints 1-4 of fore tarsi each with a small short black spine beneath. Mesosternum with a transverse black spot. Sternites densely punctured and very shortly pubescent. Parameres slightly emarginated at apex, dark, with longitudinal yellow spot (Fig. 1). ..... **palaestinensis Lohrm.**
40 (37) Fore tarsi broadened, wholly yellow. Mesosternum almost wholly dark. Venter very finely and densely punctured, and very shortly pubescent. Parameres black, with oval yellow spot at the obliquely truncate apex (Fig. 2). ..... **alfierii sp. n.**

2. Females

1 (32) Sternites III-V at least in the middle smooth and shining, without very fine and dense puncturation, the punctures visible at a tenfold magnification.
2 (3) Length 19-20 mm. Ferruginous, scutum black with yellowish design. Legs ferruginous. Wings shaded with brown, their length 14.5 mm. Metatarsus of fore legs broad, joint 2 transverse ..... **fischeri Spin.**
3 (2) Smaller species.
4 (5) Abdomen and thorax wholly or almost wholly black. Hind tibiae blackened, ferruginous at base, middle tibiae only beneath yellow ..... **turca Dahlb.**

(1) *Bembyx joeli* BytS. may come in here. It belongs to the *gracilis*-group, is larger, and has in the male a higher, pointed platform on sternite VI, and broader parameres; it has large discal spots on the tergites (Palestine).

5 (4) Abdomen with rich yellow or pale greyish-yellow design or even predominantly yellow above.

6 (9) Venter at least on sternite II ferruginous.

7 (8) Antennal 3 not longer than 1. Pilosity of vertex and thorax slightly ferruginous. Second cell of hind wing with right to slightly pointed lower apical angle. Antennae ferruginous. Mesosternum for the major part black. Clypeus dark at base. 5th joint of fore tarsi well twice as long as broad ..... **doriae Magr.**

8 (7) Antennal 3 somewhat longer than 1. Pilosity of vertex and thorax whitish. Second cell of hind wing with obtuse lower posterior angle. Antennal joint 1 yellow. Mesosternum yellowish with sharply defined black median spot. Clypeus yellow. 5th joint of fore tarsi almost three times as long as broad ..... **rufiventris sp. n.**

9 (6) Venter more or less yellow and black, or almost wholly yellow.

10 (21) Venter wholly pale, or pale with black markings; sternite II for the major part pale, sometimes with black median spot or cross fascia; posterior yellow cross bands of sternites not interrupted.

11 (14) Puncturation of sternite II very coarse, even somewhat longitudinally rugose, leaving along middle a smooth longitudinal line.

12 (13) Smaller, 12-14 mm. Sternite II with black basal cross band ..... **radoszkowskyi Handl.**

13 (12) Larger, 14-15 mm. Sternite II with black sub-basal cross band showing two lobes at posterior margin ..... **radoszkowskyi Handl. var.**

14 (11) Puncturation of sternite II moderately coarse, sparing. Sternite II without indication of an unpunctured smooth median line.

15 (16) Antennal joint 3 somewhat longer than 1. Apical tergite and also tergites IV and V at the margins ferruginous. Middle of venter longitudinally ferruginous ..... **cf. rufiventris sp. n.**

16 (15) Antennal 3 about as long as or shorter than 1. Tergite VI black and yellow. Venter without ferruginous coloration.

17 (20) Sternites III-V very sparingly punctured, even so at base. Black markings of hind femora situated near fore margin or wanting. Hind tibiae interiorly (seldom also posteriorly) with a black line, or wholly yellow.

18 (19) Posterior cell of hind wing pointed at the apex below. Antennal joint 3 somewhat shorter than 1. Sternites III-VI only in the middle of the base somewhat black. Pale colour greyish-yellow. Tergite VI mostly with black median line and tip ..... **olivacea saharae G.M.**

19 (18) Posterior cell of hind wing closed by an about vertical, not oblique, vein. Antennal 3 about equalling 1. Pale abdominal colour yellow. Sternites III-VI more broadly black. Tergite VI black or with yellow tip ..... **cf. melanura Moraw.**

20 (17) Sternites III-V across base with distinct fine puncturation, more densely punctured at the sides. Hind femora black posteriorly along middle, not near fore margin. Cut 1 of hind wing vertical. Sternites II-V narrowly yellow at the hind margins ..... **frey-gessneri decipiens nov.**

21 (10) Venter all along the middle broadly black, sides with yellow spots; seldom are the fine posterior margins of the sternites II-V yellowish transparent.

22 (23) Stout form, with short, broad abdomen. Pale colour yellow. Black spots on tergite II not separated. Apical tergite with yellow spots, seldom black. Wings usually slightly shaded with brown. Antennal 1 yellow beneath ..... **picturata BytS.**

23 (22) More slender species. Wings always hyaline. ,,

24 (27) Antennal joint 1 black, flagellum darkened or black. Femora, excepting apex, dark, if paler, then striped *above*.

25 (26) Tergite VI evenly punctured. Antennae brownish-red at apex below, joint 3 somewhat shorter than 1. Labrum always broadly blackened along middle. Metatarsus of fore leg blackened beneath. Hind tibiae, as a rule, interiorly and posteriorly lined with black. Sternite II very densely punctured at the sides ..... **lusca Spin.**

26 (25) Tergite VI scarcely punctured or smooth along middle. Antennae almost wholly black, joint 3 at least as long as 1. Labrum seldom darkened. Fore tarsi yellow. Hind tibiae only interiorly lined with black. Sternite II at the sides not so densely punctured, shining ..... **oculata Latr.**

27 (24) Antennal joint 1 yellow, often black above.

28 (31) Middle and hind femora black at most in basal half, or only lined with black. Middle and hind tibiae wholly yellow or scarcely lined. Propodeum with yellow markings.

29 (30) The black femoral stripe stituated near upper margin. Clypeus yellow. Sternite I wholly or for the major part yellow. Sternite II at the sides more finely and densely punctured than in the middle but yet shining. Tibiae with black line interiorly, middle tibiae sometimes wholly yellow..... ..... **melanura Moraw.**

30 (29) The black stripe of the middle and hind femora not near the fore margin. Clypeus narrowly black at base. Sternite I predominantly black. Sternite II more densely punctured, at the hind angles very densely so, almost dull. Tibiae pale yellow ..... **frey-gessneri Morice**

31 (28) Middle and hind femora yellow at tip only; middle and hind tibiae with black line interiorly and posteriorly. Propodeum dark. Tergite I dark, with narrow pale band, black spots on tergite II always fused with the dark base. Clypeus broadly black at base. ..... **abragensis sp. n.**

32 (1) Sternites III-V with very fine and dense puncturation and pubescence, dull or scarcely shining, the punctures not distinctly noticeable at a tenfold magnification.

33 (40) Venter broadly black all along middle, marked with yellow only at the sides.
34 (39) Tergite VI black.
35 (36) Cross vein closing posterior cell of hind wing strongly oblique. Temples slightly widened downwards. Clypeus wholly or mainly yellow.
a (b) Metatarsus of fore leg between the 9 comb spines with small hairs of varying lengths. Larger, 17-18 mm. ..... **palaestinensis Lohrm.**
b (a) Metatarsus of fore leg between the 8 comb spines without small setae. Smaller, 13-14 mm. ..... **alfierii sp. n.**
36 (35) Cross vein closing posterior cell of hind wing, though curved, almost vertical. Temples narrow. Clypeus dark
37 (38) Middle femora darkened at the base only. Middle and mostly also hind tibiae wholly yellow ..... **nilotica sp. n.**
38 (37) Middle femora and tibiae with black lines. Labrum and almost the whole clypeus black ..... **kohli Morice**
39 (34) Tergite VI yellow at the apex. Thorax above with yellow U-shaped spot ..... **pallescens sp. n., var.**
40 (33) Venter not all along the middle broadly black; either wholly yellow or at least on sternites II and III predominantly yellow.
41 (42) Antennae comparatively short, joint 3 decidedly shorter than 1. Tergite VI without raised median area. Apical tergite black, with yellow lateral spots of varying size. Sternite II slightly shining in the middle, disk with some larger punctures. Temples slightly widened ..... **chopardi Berl.**
42 (41) Antennal 3 about as long as 1, if shorter, then the temples narrow.
43 (44) Sternite II with black transverse band; everywhere without larger punctures between the fine puncturation. Median area of tergite VI scarcely elevated ..... **pallescens sp. n.**
44 (43) Sternite II yellow or with short black median line or spot, or also lateral spots.
45 (46) Tergite VI without raised median area. The pale U-shaped spot on the mesonotum always somewhat orange in front. Abdomen with black separated transverse dots on tergites I-III. Tibiae without black lines. Wings of normal length ..... **dahlbomi Handl.**
46 (45) Tergite VI with distinctly separated median area. Mesonotum seldom with faint yellow stripes. Tergites without separated black transverse spots. Wings only twice as long as the breadth of the thorax .. **chlorotica Spin.**

Group of *B. hedickei* Giner Marì

Bembyx palaestinensis Lohrmann

(Fig. 1)

1942. *Bembex palaestinensis* Lohrmann, *Mitt. Münchner Ent. Ges.*, XXXII, p. 208.
1955. *Bembix palaestinensis* De Beaumont and Bytinski-Salz, *Bull. Res. Counc. Isr.*, V (1), p. 44.

Male : 20 mm. — Face, labrum, antennal joint 1 yellow, with two dark oblique dots above insertion of antennae and transversely dark vertex, and with

temples above narrowly, towards mandibles broadly, yellow. Antennals 2-4 yellow beneath, the remaining flagellum *orange*, joints 3-5 (-6) brownish above, but apex of antennae not darkened. Prothorax posteriorly and laterally margined with yellow. Thorax above wholly black, like the propodeum, sterna yellow with black transverse spot on each side in front of middle coxae, and some small dark dots at the pleurae. Abdomen black, with comparatively *narrow whitish-yellow* (colour as in *chlorotica*) transverse fasciae on tergites I-IV (-V), the fascia on tergite I more distinctly widened laterally. Venter *black*, only sternite II with whitish spot at the sides, sternites II-III at hind margins only very finely lined with white. Legs yellow, joints 1-4 of fore tarsi at apex below with a small (short) *black spine* each; femora at the posterior face lined with black, middle tibiae indistinctly blackened at the posterior apex, hind tibiae (mainly posteriorly) with black line in their distal portion. Wings hyaline.

Temples widened downwards. Labrum long, well twice as long as broad at base (glossa exserted 7 mm. long). Antennal 1 slightly thickened, 3 scarcely longer than 1, the joints from 6 onwards to 9 with 1-2 very fine teeth, joints 10-13 concave below, 12 straight interiorly, 13 strongly curved, pointed or slightly rounded at tip. Frons above antennae hardly as broad as one eye, orbits from antennal base downward distinctly divergent. Pubescence of thorax whitish. Rt 1 of fore wing slightly curved, but below little bent inwards; cross vein of posterior cell of hind wing strongly oblique, as in *chlorotica*. Fore tarsi *not* widened, metatarsus with 9 short comb spines and, between them, *with a great number of small hairs*. Middle tibiae at the apex produced into a *short* blunt process bearing a short spine-bristle. Metatarsus of mid leg slightly thickened at the apex, pointed interiorly and there, just before apex, with several ferruginous small raised spines. Abdomen below *very finely and densely* punctured and shortly pubescent, sternites I and II (the latter in front) with longer, raised pilosity. Carina on sternite II large, platform on VI comparatively small, though distinctly tooth-like in profile, declivous part *with carina*; sternite VII flat, shining, with 1 median keel, broadly rounded at the apex. Tergite VII shining, little and indistinctly rugosely punctured, rounded at the apex and slightly emarginated at its middle. Parameres of the phallus black, broadly yellow at the apex within and emarginated, and with an indistinct blunt hump at the exterior margin, visible in a certain direction.

FEMALE : 18 mm. — Coloration as in the male, but antennae above darkened almost to the tip. Sides of thorax narrowly, hind margins of scutella narrowly, and propodeum *richly*, marked with yellow. Fasciae on abdomen broader, very much as in *chlorotica*, tergite V with pale transverse spot in the middle. Venter *black*, sternites I-III laterally with yellow spots. Metatarsus I with 9 long comb spines, and small hairs between them, without dark spines on the tarsal joints beneath. Apical (VI) tergite black, with scarcely indicated elevation, a weak lateral carina, little punctured above, shining.

HABITAT : Four specimens were taken by M. SHAFIK between Borg-el-Arab and Abuseer (iv. 1956) (coll. Cairo University).

At first sight this species has the appearance of a large *B. chlorotica*, but differs, apart from the male characters and its larger size, by the black venter and the maximum number of comb spines.

Bembyx alfierii sp. n.

(Figs. 2-4)

MALE : 15-15.5 mm. — Shape as in *B. turca*, i.e. rather broad. Face with clypeus and mandibles (tips dark) yellow, with two black oblique dots above antennae, vertex black. Antennae yellow to ferruginous, flagellum darkened above, but only slightly so towards tip. Femora broadly blackened at their posterior face, fore tibiae exteriorly, middle and hind tibiae posteriorly with strong black line, fore tarsi yellow, not spotted with black. Prothorax above black, laterally yellow, prosternum with two large black spots. Mesonotum black, with two yellow lateral spots, scutellum dark, only with lateral dots, post-scutellum only with faint yellow margin. Propodeum black. Thoracic sterna black, transversely yellow in front. Coxae yellow and black. Abdomen above black, with full yellow transverse bands on the tergites I-IV; the band on IV narrow, tergites V (and VI) with yellow central spot; tergite VII black. Sternites black with small yellow spots on segments I-III, at their posterior angles. Wings hyaline.

Temples distinct, somewhat widened downwards. Between the antennae a faint keel. Antennal joint 1 slightly widened towards apex, slightly enlarged, as a whole; joint 3 about as long as 1; joints 7-10 with a small basal tooth, even joint 12 with the trace of a small such tooth and distad, at the posterior edge, slightly concave, at the upper edge almost straight, between the two edges furrowed; joint 13 curved, apex very narrowly rounded, not truncate. Metatarsus of fore legs slightly widened towards apex, with 7-8 comb-spines which are comparatively *short*, shorter than tarsal joint 5, the joints 2-4 are slightly enlarged; interior edge of tarsal joints 2-4 with very short, not long and curved, bristles. Middle tibiae widened towards middle and then narrowed again towards apex so that they show a slight convexity within; apex of tibia with a conspicuous, rather stout thorn. Metatarsi of mid leg parallel-sided at base but widened in the two apical thirds, without bristles in this basal portion, but at the apical dilatation with a row of very small setae to tip within. Thorax dull, with very fine and dense puncturation. Sternites very finely and densely punctured and finely (not quite decumbent) pubescent, sternite I and base of II with longer, raised pubescence. Sternite II with stout tooth, VI with weak platform, VII with distinct but fine median carina. Fore wing having cross vein Rt 1 only slightly curved below. Cross vein of 2nd cell of hind wing distinctly oblique, with obtuse posterior angle (about as in *chlorotica*). Parameres broad, obliquely truncate at apex, with two blunt teeth, one at the end of the truncation within, the other at the exterior margin far from apex; parameres blackish, deep yellow at the apex, and with a roundish pale yellow spot at the apex, which does not attain the apex exteriorly but fuses with the yellow colour of it interiorly (Fig. 2).

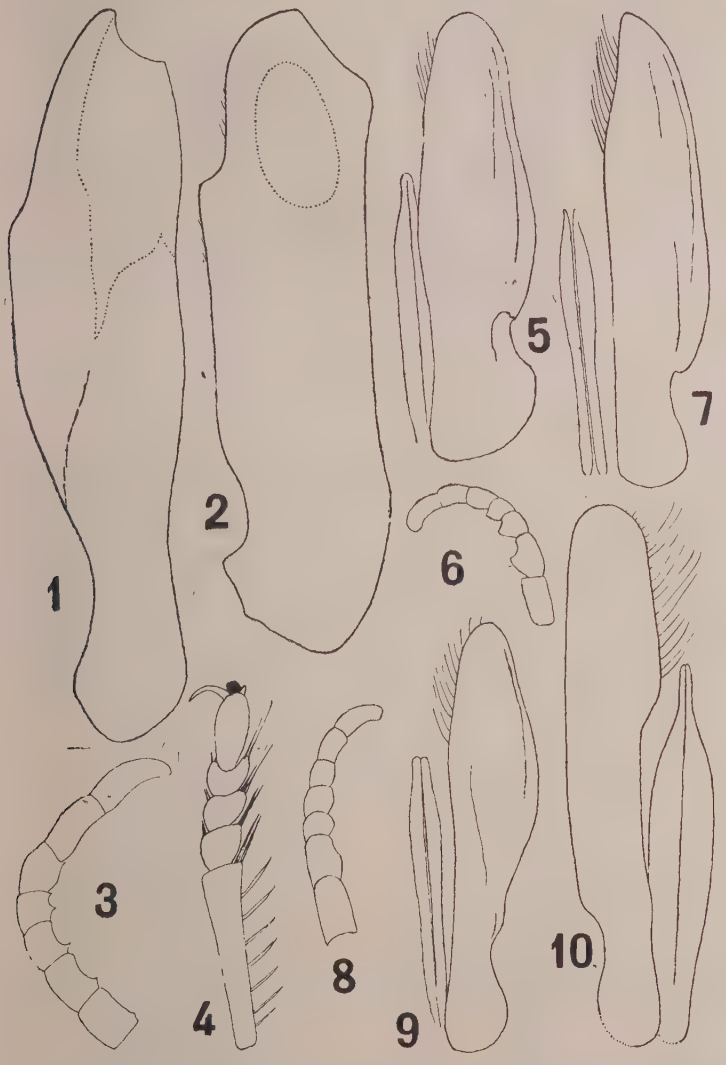

FIG. 1 : *Bembyx palaestinensis* Lohrm., paramere (space surrounded by dotted line indicates pale area), length 3.3 mm. — FIG. 2 : *Bembyx alfierii* sp. n., paramere (space surrounded by dotted line indicates pale area), length 2.5 mm. — FIG. 3 : *Bembyx alfierii* sp. n., antenna of male. — FIG. 4 : *Bembyx alfierii* sp. n., metatarsus I of male, length 3.7 mm. — FIG. 5 : *Bembyx kohli* Mor., paramere and aedoeagus, length 1.9-2 mm. — FIG. 6 : *Bembyx kohli* Mor., antenna of male.— FIG. 7 : *Bembyx nilotica* sp. n., paramere and aedoeagus, length 2 mm. — FIG. 8 : *Bembyx nilotica* sp. n., antenna of male. — FIG. 9 : *Bembyx pallescens* sp. n., paramere and aedoeagus, length 1.8 mm. — FIG. 10 : *Bembyx rufiventris* sp. n., paramere and aedoeagus, length 2.2-2.3 mm.

HABITAT : 1 male, Kerdasa, 11. iv. 1926 (coll. ALFIERI).

Dr. DE BEAUMONT made (in litt.) the following remarks about the male of this species : "It comes near the type of *B. hedickei* Giner Marì, and also to a specimen from Tunisia I possess. The type of *B. hedickei* differs by its smaller size (13 mm.), the sides and the sternum of the thorax being nearly wholly pale, the tergites I-VI having full transverse bands, the sternites more extensively marked with yellow, but the lateral mesonotal spots being narrower. The spines of the fore tarsi are longer, the middle tibiae more distinctly deformed, the platform of sternite VI more elevated. The parameres are narrower at the apex, without having a tooth exteriorly, and with the yellow spot smaller. The specimen from Tunisia is of an intermediate coloration; it resembles *B. alfierii* by the shorter comb spines and by the form of the middle tibiae; it has on sternite VI a larger platform which is rounded at the apex. The parameres are narrow at the apex, having a tooth at the exterior margin and a yellow spot of intermediate size. Otherwise the three forms are very similar in the shape of the antennae, the slightly widened joints 2-4 of the tarsi, the slightly curved middle tibiae, the metatarsus of the mid leg having a row of small setae in its apical portion interiorly, the shape of sternite VII and the general characters of the genital armature".

Dr. DE BEAUMONT agrees with me in that this form is specifically different from both, *B. palaestinensis* and *B. hedickei* as well.

FEMALE : 13.5-14 mm. — Vertex black, frons pale yellow with an almost x-shaped double spot, labrum and clypeus pale yellow, the latter with a brown dot in the middle; exterior orbits pale yellow. Antennal joint 1 pale yellow, somewhat ferruginous above like the whole flagellum which is above especially on joint 3 (antennal) slightly darkened. Thorax and the scutella black, the sides of the former and the hind margins of the latter pale yellow. Propodeum yellow, with two transverse arched black lines. Abdomen greyish- to greenish-yellow, base of tergite I with large black spot, tergites II and III (or also IV) narrowly black at base, with two large black spots connected with the fore margin; spots on V small; tergite VI black; sterna of thorax yellow, prosternum with two black dots, metasternum with two pairs of black spots at the hind margin. Abdominal sternites broadly black all along the middle, sternite I with yellow hind margin, II-IV with yellow lateral spots. Wings hyaline. Femora and middle and hind tibiae lined with black posteriorly; tarsi yellow.

Antennal joint 3 scarcely longer than 1. Clypeus protruding, dull. Thorax very finely and densely punctured, dull. Metatarsus I with 8 comb spines, without fine hairs between them. Wing length 9.5 mm, width of thorax slightly more than 4 mm. Tergite VI little punctured medially, shining, raised area scarcely noticeable. Sternite II at base with weak median elevation, posteriorly with broad but very flat impression. Puncturation very fine and dense, pubescence very short, only on sternite VI somewhat longer and obliquely raised, and the puncturation of it less

dense, this sternite therefore slightly shining. Vein Rt 1 of fore wing very little curved below; cross vein of 2nd cell of hind wing strongly oblique. its lower exterior angle obtuse.

HABITAT : 1 female (allotype), Kafr Hakeem, 2. v. 1934 (coll. Min. Agric.).

GROUP OF *B. chlorotica* SPIN.

Bembyx chlorotica Spinola

1812. Unnamed, Savigny, Descr. d'Egypte, Hym., pl. 16, fig. 4 (female).
1838. *Bembex chlorotica* Spinola, *Ann. Soc. Ent. France*, VII, p. 469.
1893. *Bembex chlorotica* Handlirsch, *Sitzb. Akad. Wiss. Wien*, CII, p. 727, pl. I, fig. 12; pl.VI, fig. 10.
1942. *Bembex chlorotica* Honoré, *Bull. Soc. Fouad I Ent.*, XXVI, p. 61.
1951 (1952). *Bembex chlorotica* De Beaumont, *Boll. Ist. Mus. Zool. Univ. Torino*, III, p. 46.

MALE : Clypeus, labrum, orbits, the major part of the prothorax, narrowly the sides of the mesonotum, crescent bands of the scutella and the propodeum and its sides, pale yellow. Antennal joint 1 and 2-3 (below) yellow, flagellum orange, darkened above. Tergites I-V with broad, pale yellow, anteriorly sinuated cross bands, tergite VI yellow, black at base. Thoracic sterna for the major part yellow, only with black spots. Sternites mostly pale yellow, II often with dark median longitudinal line, the following sternites in the middle of the bases black (more broadly so distad), sternite VI black. Femora with black lines towards the fore margin. Tibiae with dark line posteriorly. Tarsi dotted with black beneath. Wings hyaline.

Clypeus protruding, moderately long. Temples widened downward. Antennal joint 1 only slightly thickened, scarcely shorter than 3, joints 8 and 9 with small tooth. Fore tarsi simple, metatarsus with 8 comb spines. Middle femora denticulate, middle tibiae with apical bristle-bearing spine, tarsi simple. Thorax dorsally with very fine and dense puncturation. Rt 1 of fore wing very little curved below, cross vein of hind wing strongly oblique, slightly curved, the lower exterior angle of the cell obtuse. Sternite II with large, carinated hump, VI with flattened platform, VII broadly rounded posteriorly, with two widely separated, nearly parallel lateral carinae. Puncturation of the sternites very fine and dense, with extremely short pubescence. Paramera black, broadly *truncate* at the apex.

FEMALE : Coloration as in the male, though somewhat more extensively yellow, on an average; the mesonotum only seldom with a pair of fine yellow longitudinal lines, in most cases black, as in the male. Wings short, only twice as long as the width of the thorax. Tergite VI with distinctly raised median area, and therefore, with conspicuous lateral grooves, strongly shining, sparingly and coarsely punctured.

Length (both sexes) : 14-18 mm.

HABITAT : This species is not rare ; we have many records from Middle and Upper Egypt; it was also collected in the oasis Kharga and at Gebel Elba.

GROUP OF *B. megerlei* DHLB.

Bembyx kohli Morice

1812. Unnamed, Savigny, Descr. d'Egypte, pl. 16, fig. 3 (female) ?, fig. 8 (male)?
1897. *Bembex kohli* Morice, *Trans. Ent. Soc. London*, p. 313, pl. VI, figs. 32-34 (male).

MALE : 13-14.5 mm. — On the head only the vertex and a spot above the antennae, connected with the former, black; lower part of frons, clypeus and labrum yellow. Antennae yellow, joint 1 at apex, the following joints above, brownish. Clypeus strongly protruding, frons between antennal bases without distinct carina. Prothorax with yellow posterior margin, prosternum yellow with two black spots. Thorax black, sides near wing base narrowly margined with yellow, scutellum only with fine yellow postero-marginal line. Wings hyaline. Legs yellow, all femora posteriorly (middle femora more so towards the upper margin) with black line, below only at base with black marking; fore tibiae exteriorly, middle tibiae posteriorly, with black line, hind tibiae yellow or at base with a short dark line posteriorly. *Abdomen for the major part black*, with a yellow fascia on tergite III, which is narrow and medially interrupted, and with lateral transverse spots on I and IV, or less marked with yellow. Mesosternum predominantly black, only laterally and in front somewhat yellow. Venter in the middle for all its length black, sides of sternites I-III with transverse, yellow triangular spots, humps on sternites II and VI black.

Antennal joint 3 little shorter than the slightly conical joint 1, joint 7 with a slight angle at the apex within, 8-10 with distinct small tooth-like angles, 8 strongly almost semi-circularly excavated in distal half within, joint 12 slender, almost straight interiorly, 13 strongly curved, rounded to truncate at the apex. Temples narrow. First cubital cross vein only very slightly curved below, cross vein of hind wing slightly curved, vertical. Middle femora slightly and finely dentate in basal half, and with about three widely separated stouter yellow teeth in apical half. Middle tibiae curved, i.e. thin at base, then convex interiorly, with a fine lamella as in the following species, and slender again in apical fourth; metatarsus with an emargination in posterior half within and in front of it with two distinct bristles (as in *ganglbaueri* Hdl., pl. III, fig. 23). Tibial spine present but short, with small terminal seta, calcar conspicuous. Sternite II of the abdomen with sharply carinated tooth-like hump which is posteriorly concave in profile, sternite III with very slight median carina, sternite VI (as against *nilotica*) with blunt platform that is gradually declivous posteriorly, sternite VII with little raised, inconspicuous carina in the middle. Sternite II very finely and densely punctured and with decumbent pubescence, raised hairs are present on sternite I, a few on II; sternites III-V with somewhat less dense, but fine puncturation and very short, slightly raised pubescence.

HABITAT : MORICE's specimen was taken at Sakkara. Specimens in the collection of the Ministry of Agriculture are from Masghuna and Samalout, and 2 specimens collected by Dr. TAHER SAYED (coll. Ain Shams Univ.) are from Balteem.

DE BEAUMONT has compared one of the examples, as described above, with MORICE's type, and found them identical. The female, taken by MORICE with the male, is yet doubtful as belonging to this species, and also is the female described below which, though belonging to the *megerlei*-group, is of stouter build and has a dark face and complete pale fasciae of the abdomen.

Bembyx sp.

FEMALE : 14.5 mm. — Frons, clypeus and labrum blackish, with fine, silver-white pubescence. Yellow are only the mandibles (with dark tips) and a small spot in the anterior angles of the clypeus, the orbits (very narrowly) and a dot below the 1st ocellus. Antennal joint 1 yellow, all along within and at base blackened, articulations yellow; flagellum ferruginous below, blackened above. Pubescence of head whitish. Prothorax yellow, with two black spots above. Scutellum and post-scutellum margined with yellow posteriorly, mesonotum black, with yellow margins and dorsally with narrow, posteriorly interrupted, yellow U-spot. Propodeum black, with yellow crescent and yellow at the sides. Markings of the abdomen dorsally about as in *B. chlorotica*, colour of the pale fasciae as in this species (pale greenish-grey), tergite VI wholly black. Fore femora posteriorly, middle femora about to middle (irregularly), hind femora for the major part, black. Fore tibiae exteriorly, middle tibiae interiorly, hind tibiae posteriorly slightly lined with black. Mesosternum black, only with a lateral dot in front. The whole venter black, only the sternites II and III with a small pale lateral spot.

Antennal joint 3 little shorter than 1. Clypeus somewhat protruding. Frons at the narrowest part distinctly broader than one eye. Thorax and scutellum not shining, very densely punctured. Tergite VI with only very slightly raised median area, dorsally sparingly and irregularly, somewhat rugosely punctured, strongly shining. Metatarsus of fore leg with 7-8 comb spines. The sternites of the abdomen are very densely and finely punctured, with mainly adpressed pubescence, raised hairs being visible only on sternites I, II and VI; sternite II with a shallow longitudinal impression.

HABITAT : 1 female, Port Said, leg. Dr. LOTTE (coll. ALFIERI); 1 female, Abu Rowash, 5. vi. 1928 (coll. Min. Agric.).

Bembyx nilotica sp. n.

(Figs. 7 and 8)

MALE : 12-15.5 mm. — Pale parts of head, thorax and legs yellow, fasciae of abdomen pale yellow. Antennae yellow, tip of joint 1 dorsally, and flagellum dorsally darkened. Vertex and a spot on the frons (with yellow centre) black. Thorax margined

with yellow and sometimes with two narrow dorsal lines, scutellum mostly margined at the sides and behind. Propodeum with yellow transverse crescent-line and yellow sides posteriorly. Abdomen with narrow black anterior and posterior marginal fasciae which are medially broader at the bases of the tergites II and III (as no dark spots are separated), tergite V black with yellow fascia or two lateral spots, tergites VI and VII black. Venter all along the middle black, sternite I with small posterior central spot, II-IV with yellow lateral spots, decreasing in size towards apex of abdomen; carina on II and platform on VI black. Legs with fore and hind femora posteriorly lined with black (mainly towards posterior margin), middle femora yellow, *alll tibiae yellow*. Mesosternum posteriorly with large black lateral spots which are fused in the middle.

Antennal joint 3 little shorter than the *slightly* enlarged joint 1, joints 8-9 slightly widened to an *obtuse* angle, 8 by far not so strongly excavated as in *B. kohli*, 12 slightly convex interiorly, 13 somewhat curved, truncate at tip. Clypeus strongly protruding. Frons somewhat higher than broad. Temples slightly widened downwards. Tarsi slender, fore tarsi simple, metatarsus with 6-7 comb spines. Middle tibia with apical spur bearing a pale stout bristle; the tibia is curved, somewhat swollen behind middle within, from base to middle with a groove within which is limited by a low pale lamella, at its upper edge; metatarsus II emarginated and with two conspicuous bristles. Middle femora denticulate, the teeth conspicuous, the distal ones somewhat more widely separated than the rest. First cubital vein of fore wing little curved below. Cross-vein of second cell of hind wing about vertical. Sternites rather densely and finely punctured and (not quite decumbent) pubescent, II with sharp tooth-like carina, VI with a dentate platform which is *concave posteriorly, in profile*; sternite VII with three fine longitudinal carinae. Tergite VII sparingly and irregularly punctured in the middle. Parameres as in Figure 7.

Closely allied to *B. kohli* this species differs by the obtuse "teeth" of the pre-apical antennal joints, the tooth-like platform of sternite VI, the tricarinate sternite VII, the broad yellow fasciae of the tergites, and the wholly yellow mid legs.

HABITAT : I saw 7 males of the species (paratypes) from Berkash, Abu-Rowash, Mazghouna and Sakkara; the holotype is from Abukeer (17.v.1915, leg. STOREY); they are in the collections of the Ministry of Agriculture, Ain Shams University and Mr. ALFIERI's, one (without locality) in the collection of the Entomological Society of Egypt.

FEMALE : Very similar to the female described below the foregoing species, but considerably paler. Clypeus dark with pale anterior spots, labrum (perhaps not invariably) with brown median stripe including an abbreviated yellow central line. On the frons, there are only a few dots yellow, above antennal base. Antennal joint 1 yellow beneath, blackened above, flagellum ferruginous, brownish exteriorly. Mesothorax black, laterally and an incomplete U-spot yellow, scutellum with broad yellow posterior margin, post-scutellum for the major part yellow. Propodeum yellow, with an anterior and posterior black crescent-spot. Abdominal tergites

with broad pale yellow fasciae, and on tergites III and IV with a pair of black transverse spots that are fused with the black bases, as in the foregoing species; the yellow bands are broader and yet full on tergite V; tergite VI black. Legs yellow, fore and hind femora with black stripe posteriorly which leaves the fore margin yellow also on the hind femora; middle femora blackened only at base, posteriorly. *Fore and middle tibiae wholly yellow*, hind tibiae yellow or with an indistinct black line posteriorly. Sternites black, only II and III with pale yellow lateral triangular spots. Mesosternum black, in front slightly yellow laterally.

Antennal joint 3 somewhat shorter than 1. Metatarsus I with 7 comb spines. Sternites of the abdomen with extremely fine and dense puncturation, sternite II with a shallow median longitudinal depression. Tergite VI more sparingly and irregularly punctured in the middle, and there is no distinctly limited, only posteriorly indicated, raised area; lateral margin of the tergite slightly sinuated. First cubital vein only very slightly curved inward below, second cell of hind wing with vertical cross vein. Temples as in the foregoing species.

HABITAT : 1 female, Borgash, 5. iv. 1934 (coll. Min. Agric.).

It is by no means absolutely certain that this form belongs to *nilotica*, and I was unable to find other than colour differences as against the form described above.

Bembyx pallescens sp. n.

(Fig. 9)

MALE : 10.5-13 mm. — A small species of predominantly yellow colour. Face yellow, tips of mandibles reddish, frons with W-shaped black spot, vertex black. Antennal 1 yellow, apex above with black dot, flagellum ferruginous below, brownish above. Prothorax yellow, with black spots above. Mesonotum black, sides yellow, two fine dorsal lines or U-spot yellow; scutellum and post-scutellum broadly margined with yellow. Propodeum black, posteriorly and at the sides broadly yellow, and with yellow median line. Tergite I of abdomen yellow with large black basal spot; yellow bands on each of the tergites II-V, the apical bands sometimes interrupted; on tergites II and III there are two black transverse spots which are either free or fused with the dark fore margin; tergites VI and VII black. Mesosternum yellow in front, transversely black posteriorly, margin of blackening dented. Sternites I - III yellow, I with black median spot or line, IV black with yellow sides V with small yellow lateral spot, VI and VII black. Legs yellow, femora lined with black behind, fore and middle tibiae *behind* with black line, hind tibiae with or without *posterior* black line; joints of fore tarsi partly with small black dot which may also be indicated on the middle tarsi. Pubescence of body rather dense, whitish.

Clypeus somewhat protruding. Mandibles very slender, tooth small. Temples quite narrow. Antennal joint 1 little enlarged, joint 3 almost as long as 1, joint 7 with indistinct, 8 with more conspicuous small tooth, 8 and 9 commonly emarginated, 12 straight at the interior margin, 13 curved, *truncate* at the apex; antennae little widened towards apex. Inner orbits not diverging downwards. Thorax dull above,

extremely finely and densely punctured. Middle femora only in distal half with a few widely separated pale teeth. Middle tibiae slightly curved, about as in *B. kohli* and *B. nilotica*, apical spine present, but small; middle tarsi with a slight emargination within, in front of which there are 1-2 unequal bristles. Sternite II with weak, dentate carina, sternite VI with an anteriorly gradually declivous platform that is steeply declivous posteriorly, forming a short point; in small specimens carina and platform are weaker. Sternite VII with slight median carina; sternites very finely and densely punctured; tergite VII shining, little punctured, rounded at apex. Parameres (Fig. 9) straight at interior margin, gradually rounded to tip at the exterior margin, forming there almost an angle. Wings hyaline, vein Rt1 of fore wing little curved, cross-vein of second cell of hind wing vertical, normal.

FEMALE : 10.5-12.5 mm. — Colour similar to that of male, but the prothorax wholly yellow, the yellow stripes on mesonotum rather broad, post-scutellum wholly yellow and the black crescents reduced to narrow curved lines. Tergites yellow, I at base with black transverse line, in the middle with two round black dots; tergite II with small black median triangle at base and 2 transverse spots, II as well (also perhaps IV but base concealed); V with fine black posterior margin, VI blackened at base but for the major part yellow. Femora with fine black posterior line, *tibiae and tarsi wholly yellow*. Sternites yellow with black transverse band in front of middle of II, black fore margin of III; sternites IV and V black, IV with yellow lateral spots, VI yellow at apex. Mesosternum yellow, at the sides with black oblique spot.

Antennal 3 about as long as 1. Tergite VI shining, medially almost smooth, raised area indistinct. Sternites extremely finely and densely punctured, II with a shallow median longitudinal depression. Wing length about 10 mm., width of thorax 3.5 mm. Venation as in the male. Fore tarsi with 7 pale comb spines.

HABITAT : 1 male (holotype), Khanka, 27.v.1914; 1 female (allotype), Romani, 23.viii. 1916 (coll. Min. Agric.); paratypes from Giza (Min. Agric.) and Wadi Digla (coll. PRIESNER).

A specimen from Balteem (coll. Ain Shams Univ.) has the sternites from II onwards medially black, II with large, III and IV with small yellow lateral spots; it is obviously an extremely dark individual of the same species.

B. pallescens is a true member of the *megerlei*-group, differing from the other species by the smaller size, being scarcely as long as *B. radoszkowskyi*, and the considerably paler coloration.

GROUP OF *B. fischeri* SPIN.

Bembyx fischeri Spinola

1838. *Bembex fischeri* Spinola, *Ann. Soc. Ent. France*, p. 470 (female).
1897. *Bembex nasuta* Morice, *Trans. Ent. Soc. London*, p. 314, pl. VI, figs. 35-39 (male).
1951-1952. *Bembex fischeri* De Beaumont, *Boll. Ist. Mus. Zool. Uni. Torino*, III, p. 46.

MALE : ca. 25 mm. — According to MORICE similar to *B. rostrata* L. Antennal joint 1 below much less stout, joints 7-10 dentate, 11-13 excavated, 13 much slenderer

and longer. Tergite VI not rounded but truncate with lateral angles conspicuous. Sternite VIII for the major part with parallel sides, before apex produced into a rather abruptly contracted tooth. Parameres at interior margin very distinctly excavated which is hardly the case in *B. rostrata*. Middle femora dentate. First metatarsus with 7 comb spines. Ventral tubercles as in *B. rostrata*. The pale coloration of the abdomen is in the single specimen nowhere really yellow : it is on the disks of the segments I-III grey, otherwise orange. Yellow are nearly the whole prothorax, the posterior orbits, the space between the antennae and their first joint; the remaining face (clypeus, labrum, etc.) are whitish. Flagellum of the antennae ferruginous, with black stripe above. — Cairo.

The above is a translation from Latin of the description given by MORICE. The male remained unknown to me.

FEMALE : 20 mm. — Deep yellow to ferruginous. Head only with dark spot around ocelli, the upper angles of the eyes blackened. Clypeus and labrum yellow, tips of mandibles black; these are long, their tooth about in the middle of the interior margin. Temples in profile distinctly somewhat widened below. Antennal joint 3 well as long as 1. Clypeus protruding. Prothorax yellow, mesonotum with large, about W-shaped black spot, scutellum at base transversely dark, propodeum with narrow, transverse, crescent-shaped line, the propodeum therefore mainly deep yellow. Sterna yellow, in the middle spotted with black. Legs wholly ferruginous. Anterior metatarsus slightly widened towards apex, not quite three times as long as broad, with 6 comb spines, the first of them small. Abdomen deep yellow or orange, with fused orange markings, i.e. at the base of tergite I, and indistinct reddish transverse spots on the tergites II-IV. Apical tergite densely and not very coarsely punctured, without raised area. Fore and hind wings, especially about middle, slightly shaded with brown. Sternites shining, ferruginous, with indistinct yellow lateral spots; laterally the tergites are densely, in the middle coarsely and sparingly punctured; extreme bases of sternites II-IV very finely punctured. Cross-vein (Cut 1) of hind wing curved, vertical. First radial (cubital) cross-vein of fore wing strongly curved inward below.

HABITAT : 1 female, Gebel Asfar, 29.v.1930 (coll. ALFIERI).

Bembyx rufiventris sp. n.

(Figs. 10 and 11)

MALE : 15.5 mm. — Clypeus and labrum yellow, frons and vertex black, orbits broadly yellow, temples yellow. Antennal joint 1 yellow, with black dorsal line, flagellum black above, reddish below, antennal 3 yellow at base below. Thorax black above, laterally only at the wing base with short yellow margin; scutellum and post-scutellum black, narrowly margined with yellow posteriorly. Propodeum black, with yellow crescent-spot, broadly yellow at the sides. Tergites with broad yellow bands which show a reddish tint at base; base of tergite I black, without roundish

spots; tergites II and III with transverse spots which are fused with the base on III. Tergite VII black at base, *yellow to ferruginous at the apex*. Mesosternum posteriorly transversely black, with yellow spots at the sides. Sternites in the middle ferruginous, II with two small transverse black spots, V black at base in the middle, VI black with yellow hind margin. Fore coxae almost wholly yellow, middle and hind coxae yellow and black; femora and tibiae yellow, with black line towards fore margin, middle femora with less black than the others. Fore tibiae exteriorly with black line, middle and hind tibiae wholly yellow. Pubescence whitish.

Clypeus protruding. Temples only very slightly widened below. Antennae scarcely thickened towards apex, joint 3 well as long as 1, joints 8 and 9 with very small tooth, 12 interiorly slightly concave or straight, 13 *little* curved, rounded at tip. Fore tarsi slender, metatarsus with 6 short comb spines. Middle legs simple, femora evenly dentate. Tergite VII rounded at apex, shining above, very sparingly coarsely punctured. Parameres rather broad, rounded at the apex (Fig. 10). Sternite II with stout, posteriorly concave, keeled tooth, VI with steeply declivous and posteriorly sulcate platform. Sternite VII with *sharp median carina*. Sternite II densely punctured and shining behind, III-V sparingly punctured, shining, VI densely punctured at base and sides, platform almost smooth. Wings hyaline, 1st cubital cross vein strongly curved inward below; 2nd cell of hind wing slightly obtusely angled at the lower apex.

FEMALE: 14.5-16.5 mm. — Face yellow, frons above antennae with two black spots, vertex for the major part black. Coloration of antennae, thorax and abdomen as in the male, but tergite VI wholly pale ferruginous. Legs yellow, only the fore femora with black stripe, all femora somewhat ferruginous instead of yellow. Mesosternum with large black spot in the middle. The whole venter yellow with ill-limited reddish longitudinal stripe in the middle. Sternite V with small black lateral spots.

Temples slightly widened below, clypeus protruding, somewhat smoothened in front, sparingly punctured. *Antennal joint* 3 *distinctly longer than* 1. Frons slightly carinated between antennal bases. Fore tarsi stout, metatarsus with 6 broad comb spines. Sternites strongly shining, II with scarce coarse punctures, III-V almost smooth, VI more densely punctured, with reddish pubescence. Tergite VI shining, sparingly punctured, sides slightly undulating. Wings shorter than in the male, venation the same. Wing length 9.5 mm.

HABITAT : 1 male (holotype), 1 female (allotype), Helouan, 30.iv.1932 (coll. Min. Agric.); 1 female (paratype), Kerdasa, 17.v.1913 (coll. ALFIERI).

This species, much smaller than *fischeri*, could only be confused with *B. doriae* Magr. but is distinguished by the simple middle tarsi of the male, the shorter antennal 1, the shorter wings, the paler venter, the slenderer shape, the slightly obtuse 2nd cell of the hind wing, the shorter claws, etc. It comes no doubt closest to *B. brunneri* Hdl. but differs by the lack of the yellow markings on the mesonotum, the wholly yellow tergite VI of the female, the wholly yellow to ferruginous sternites and the more strongly and evenly rounded parameres of the male.

GROUP OF *B. fuscipennis* LEP.

Bembyx doriae Magretti

(Figs. 12 - 14)

1884. *Bembex doriae* Magretti, *Ann. Mus. Stor. Nat. Genova*, XXI, p. 590, pl. I, fig. 14 (male and female).
1893. *Bembex fischeri* Handlirsch (nec Spin.), *Sitz. Akad. Wiss. Wien*, CII, p. 215 (female).
1942. *Bembex arabica* Lohrmann, *Mitt. Münchner Ent. Ges.*, XXXII, p. 208.
1950. *Bembex doriae* Guiglia, *Ann. Mus. Stor. Nat. Genova*, LXIV, p. 240, figs. 1-4.

MALE : Labrum, clypeus (partly or wholly) and interior orbits more or less narrowly ferruginous, posterior orbits more yellow. Antennae ferruginous, above or wholly blackened, excepting joint 1 which is ferruginous. Thorax black, only the margins of the prothorax and the sides above wing base slightly brownish. Posterior margin of the scutellum, an arched line and the hind angles of the propodeum brownish. Pubescence of the thorax dorsally somewhat reddish, laterally like at the sides of the propodeum more grey, at the frons whitish. Abdomen black with yellow transverse bands on tergites I-VI; tergite II almost always with separated transverse black dots, I broadly blackened at base, never with separated round spots. Underside of thorax black, only the angles of the prosternum ferruginous, sternite I partly, II in the middle red-brown, the remaining sternites with black and ferruginous fasciae and small yellow lateral spots; tergite VII dark. Legs ferruginous, femora more reddish, tibiae more yellow; sometimes middle and hind tibiae within, fore tibiae beneath, with dark stripe.

Temples only slightly widened below. Antennal joint 3 distinctly shorter than 1, though at least 4 times as long as broad at apex, joints 8-10 with small tooth, 11 and 12 thickened, at least in one direction slightly convex within, 13 curved, strongly convex at outer, scarcely so at inner margin and indistinctly obliquely truncate at apex. Labrum long. Thorax densely but distinctly punctured. Middle tibiae slightly flattened, without apical spine; metatarsus II with lobiform appendage before middle within, exterior margin somewhat concave (cf. *B. sibilans* Handl., l.c. plate III, fig. 27; ARNOLD, *Ann. Transvaal Mus.*, XIII, pl. IV, p. 374, fig. 37, 1929). Mid femora without denticulation. Sternite II with *stout* (reddish), compressed hump, but in small specimens only with carina. Platform on sternite VI in large examples distinctly convex, in profile, and vertical posteriorly; elongate triangular with slightly convex sides, in ventral aspect; sternite VII in large specimens with 5 fine, not quite parallel carinae. Tergite VI without black lateral spines, VII little punctured on dorsal surface, shining, rounded posteriorly. Parameres (Fig. 12) pointed at the apex, slender at base, exterior margin much convex, interior margin *straight* and long pilose. Sternites strongly shining, unevenly set with, especially laterally, very fine and else very coarse, punctures. Wings slightly shaded, Rt 1 of fore wing strongly curved inward below, 2nd cell of hind wing only slightly pointed at exterior lower angle, cross-vein sometimes almost vertical.

Female : Very similar, orbits more broadly pale, clypeus mostly wholly ferruginous. Tergite VI ferruginous with black base and median line, in the middle scarcely, laterally densely punctured. The 6 comb spines brownish at the tips. Legs almost wholly ferruginous. Sternites ferruginous in the middle, with lateral yellow

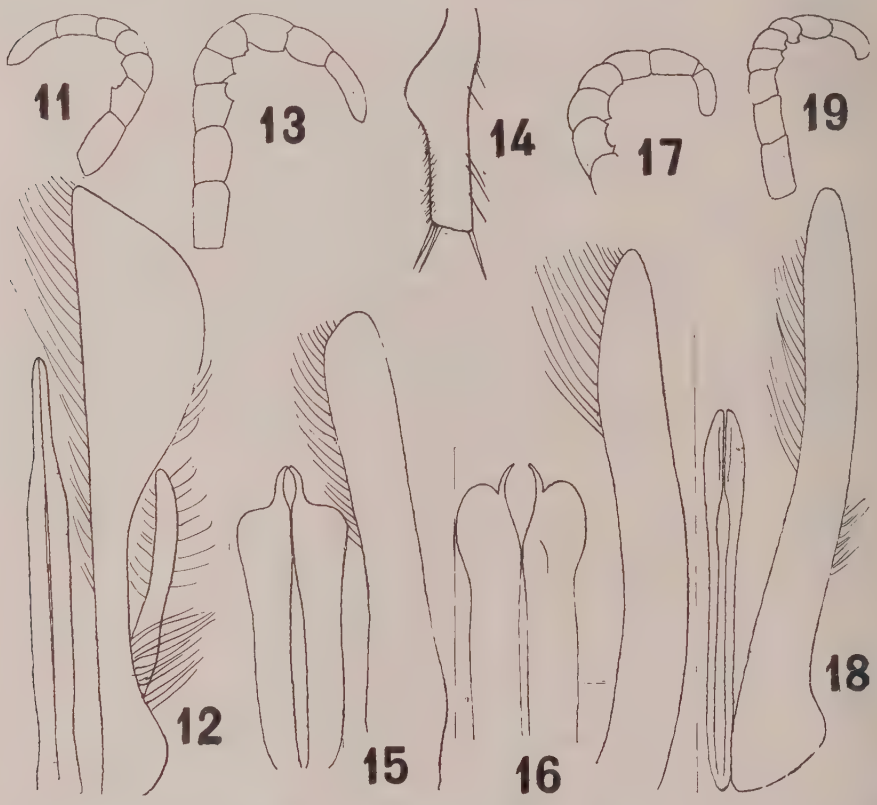

Fig. 11 : *Bembyx rufiventris* sp. n., antenna of male. — Fig. 12 : *Bembyx doriae* Magr., aedoeagus, paramere and volsella, length 2.3 mm. — Fig. 13 — *Bembyx doriae* Magr., antenna of male. — Fig. 14 : *Bembyx doriae* Magr., metatarsus II of male. — Fig. 15 : *Bembyx frey-gessneri* Mor., paramere and aedoeagus, length 1.7-1.8 mm. — Fig. 16 : *Bembyx abragensis* sp. n., paramere and aedoeagus, length 1.9 mm. — Fig. 17 : *Bembyx abragensis* sp. n., antenna of male. — Fig. 18 : *Bembyx melanura* Moraw., paramere and aedoeagus, length 2-2.3 mm. — Fig. 19 : *Bembyx melanura* Moraw., antenna of male.

spots, (II-) III-VI with black base; puncturation on sternite II coarse and scarce in the middle, denser at the sides, on the remaining sternites fine and dense at base, very scarce at the remaining surface; sternite VI slightly raised roof-like along middle. Wings as in the male.

Length (male and female) : 12.5-16 mm.

HABITAT : There are about 40 specimens of this species in the collection of the Cairo University, collected by H. C. EFFLATOUN and his assistants in Sinai (Wadi El-Legaa, Wadi El-Arbain); I found several females in the Wadis at the foot of the Elba mountains near Mersa Halaib, at the Red Sea coast.

DISTRIBUTION : Egypt (Sinai, Red Sea coast), Arabia, Erythrea.

I do not doubt that our specimens are identical with LOHRMANN's *B. arabica*, especially because of the shape of the genitalia of which LOHRMANN says that they are arched at the exterior, straight at the interior margin, and are pointed at tip. The only difference consists in that in *arabica* the bands of the abdomen are said to be whitish, while I see them yellow, in the Egyptian specimens.

According to LOHRMANN, *B. arabica* differs from *B. doriae* Magr. by the pale wings and the weaker armature of sternite II. However, none of these characters is decidedly specific. The specimens from one restricted locality in Sinai are allotropic with regard to the tooth on sternite II, some weaker examples having a straight carina ending in a small tooth that is just visible in lateral aspect, whereas the larger specimens have a stout and curved, laterally flattened tooth. The same allotropy one finds, e.g., in *B. oculata*. The shading of the wings is very faint in some smaller specimens, as it also applies, e.g., to *B. turca*.

If one compares the Egyptian specimens with the redescription of *B. doriae* Magr., given by GUIGLIA after the original material of MAGRETTI, the only apparent difference seems to be the exterior margin of metatarsus II which is straight and provided all along with short fine hairs in *B. doriae* (GUIGLIA, l.c. p. 241, fig. 2), while in the Egyptian specimens (Fig.14) the outer margin of the mid metatarsus is slightly concave and bears a few bristles; however, the above mentioned characters of *B. doriae* can also be seen in the Egyptian specimens, if the metatarsus is viewed at a slightly different angle. Of *B. doriae*, the male genitalia are unfortunately unknown.

I am of the opinion that *B. arabica* is based on a small example, *B. doriae* on larger specimens of the same species, and that both may be a northern race of *B. capensis* Lep. which agrees in the male genitalia with both, *B. arabica* and the Egyptian specimens (cf. ARNOLD, *Ann. Transvaal Mus.*, XIII (4), 1929).

GROUP OF *B. olivacea* F.

Bembyx olivacea F.

1787. *Bembyx olivacea* Fabricius, Mant. Ins., 4, p. 285.
1893. *Bembex mediterranea* Handlirsch, *Sitz. Akad. Wiss. Wien*, CII, pp. 807, 894, pl. II, fig. 15; pl. V, figs. 11, 22; pl. VII, fig. 9.
1942. *Bembex mediterranea* Honoré, *Bull. Soc. Fouad I Ent.*, XXVI, p. 61.
The Egyptian form belongs to the ssp. *saharae* G.M.
1812. Unnamed, Savigny, Descr. d'Egypte, pl. 16, fig. 1 (?).
1945. *Bembex saharae* Giner Mari, *Eos*, XX, p. 381.
1951. *Bembex olivacea saharae* De Beaumont, *Bull. Soc. Sci. Nat. Maroc*, XXIX, p. 273.
1953. *Bembex olivacea saharae* De Beaumont, *Mitt. Schweiz. Ent. Ges.*, XXVI, p. 80.

MALE : 10-17 mm. — A pale greyish- to greenish-yellow species, like *B. dahlbomi*, with comparatively much reduced black design. Head, with the exception

of a dark fronto-vertical spot, pale. Antennal joint 1 yellow, usually a small spot above dark; flagellum ferruginous, darkened dorsally. Thorax nearly always with yellow U-spot and yellow sides, scutellum and propodeum profusely marked with yellow. Mesosternum with black central spot that is not divided along middle (as this is the case in *B. dahlbomi*), pleurae with some black lines. Abdomen with base of tergite I marked with black, the spots usually divided, tergite II (and III) with a pair of small, narrow, transverse dark dots. Sternites almost entirely yellow, except the apical segments. Tergite VII yellow with usually the tip brownish. Legs yellow, dark stripes wanting or rudimentary, fore tarsi beneath usually with black dot on segments 1 and 2.

Antennal 1 longer than 3, penultimate joints not convex interiorly. Temples narrow. Thorax above with extremely dense puncturation, dull. Propodeum with comparatively long white hairs. Legs simple, only the middle femora with fine yellow dentation. Sternites shining, their puncturation scarce, denser only at the extreme sides. Sternite II with weak carina, *never with spine*. Tergite VII at the sides beyond base with a triangular tooth or excision that is often not visible when the segments are contracted. Rtl (1st cubital cross vein) of fore wing much curved inward below; cross vein of second cell of hind wing *oblique* so that its exterior lower angle is pointed. Parameres from a narrow base much broadened, narrowed again and pointed at the apex which is directed inward; interior margin excavated in apical third so that a tooth is formed about the beginning of the apical third.

Female : Coloration as in the male, with the mesopleurae mostly pale. The pale U-spot of the mesonotum mostly more conspicuous than in the male, but not orange in front (as against *dahlbomi*). Antennal 3 shorter than 1. Tergite VI yellow, with black median line and tip. Sternites smooth and shining, very sparingly punctured, more densely so at the sides, tergite VI everywhere evenly punctured, without smooth median line.

Habitat : *B. olivacea saharae* is obviously the most common species in this country; it varies more in size than in design. It is recorded from Alexandria to Assouan, and from Port Said to Mersa Matrouh. It occurs in Sinai and also in the Elba moutains.

Bembyx dahlbomi Handlirsch

1893. *Bembex dahlbomi* Handlirsch, *Sitzb. Akad. Wiss. Wien*, CII, p. 806, pl. II, fig. 14; pl. V, fig. 10.
1942. *Bembex dahlbomi* Honoré, *Bull. Soc. Fouad I d'Ent.*, XXVI, p. 61.
1950. *Bembex dahlbomi* De Beaumont, *Bull. Soc. Fouad I d'Ent.*, XXXIV, p. 8.

By the pale greyish coloration this species is at first sight extremely similar to *olivacea*. Like in this species the apex of the second cell of the hind wing is pointed at the lower angle, and it has a full U-shaped pale spot on the mesonotum, which is, however, always somewhat orange in front and not yellow as in *olivacea*. In the female, joint 3 of the antennae is not longer than 1, the face is wholly yellow, and on the thorax and the abdomen the pale colour is predominant. On the abdomen there

are usually only the apical margins of the tergites *narrowly* blackened about the middle, there are two isolated narrow transverse spots present on the tergites, and there are 4 spots on tergite I. Tergite VI yellow with black median line. Legs yellow, with black line on the femora above. Under side of the body for the major part pale, with spots on the mesosternum and usually dark sternite V (across base) and VI (wholly). Antennae darkened above. Sternites very finely and densely punctured, II with scattered shallow larger punctures; on sternite VI the puncturation is less dense and the pubescence dark and longer than on the sternites III-V.

The male is easily recognized in having the interior maring of the middle *and fore* femora denticulate. Sternite II has a carina ending in a small tooth and is densely and rather evenly punctured, whereas segments III-V are very finely and sparingly punctured, and therefore shining. Colour as in the female, the black mesosternal spots are sometimes larger but seem to be always separated in the middle, as against *olivacea* where the mesosternum is black and paler at the sides only. The fine black posterior margins of the tergites are mostly only indicated in the middle of each tergite. Tergite VII black with yellow spots or yellow with black margins, the sides are sinuated and the *apex* is *excavated*. Middle tibiae and tarsi simple. The 3rd antennal is somewhat shorter than the 1st, the joints 8-10 bear a small tooth each, and the pre-apical joints are not convex interiorly.

HABITAT : In Egypt less common than the foregoing species, but occurring all over the country. I saw specimens from Gebel Asfar, Magadla, Kerdasa, Sakkara, Helouan, Ghobbet-el-Bous, Alexandria, Siouf, Ras-el-Bar; Sinai (El-Areesh, Romani); Oasis Kharga, Bir Terfawi, Assouan. HONORÉ reports it from Kosseir. It also occurs in the Hedjas.

Bembyx chopardi Berland

1950. *Bembex chopardi* Berland, *Mém. Inst. Franç. Afr. noire*, X, p. 297, figs.

MALE : Head pale yellow, vertex with dark, sometimes interrupted, circular spot and with pale spot at the upper angles of the eyes. Frons between antennae indistinctly carinated. Antennal joint 1 pale yellow, with black spot above, flagellum pale ferruginous below, darkened above. Thorax with profuse yellow design, black, with pale U-lines and pale lateral margins. Scutellum posteriorly with pale yellow margin, propodeum with two fine yellow spots and pale sides, pilosity not dense. Joints 2-4 of the fore tarsi with dark dots beneath, fore tibiae as well. Fore femora behind, middle and hind femora more towards the upper margin, with black line; hind tibiae with two black lines, one interiorly and the other posteriorly. Abdomen pale greenish-yellow, with rich black design : tergite I broadly black at base and with black posterior margin, tergites II-IV black at base and hind margin, II and III with black transverse spots which are sometimes joined with base; VI not or scarcely blackened at the hind margin, VII black or also with 2 yellow spots posteriorly. Sterna yellow or with small black dots. Venter yellow, sternites V and VI

broadly black at base, keel stout, wholly yellow or with black line above. Wings hyaline.

Clypeus flat, little prominent. Temples slightly widened below. Antennae short, joint 3 much shorter than 1, flagellum distinctly enlarged towards apex, joints 8-11 dentate, 12 *convex* interiorly, 13 strongly curved, rounded-truncate. Sternite II rather densely, III and IV finely and moderately densely punctured, posteriorly less densely, with rugose punctures. Venter pubescent. Metatarsus of fore legs somewhat widened, with about 8 comb spines. Mid legs simple, only the mid femora denticulated. Sternite II with conspicuous carina, platform on VI conspicuous, giving off two oblique lateral carinae, VII with obtusely dentate, conspicuous median carina and a lateral emargination so that an angle is formed. Tergite VII characteristically formed, tapering towards apex, emarginated at apex, laterally with an above and below sharply edged groove, and at the upper edge with a blunt tooth (cf. *olivacea*), at the lower edge with a second, pointed tooth that is directed laterally or somewhat forwardly so that there appears between the two teeth a narrow horizontal slit.

Female : Coloration as in the male, with the difference that the yellow of the thorax is somewhat more extensive and the U-shaped spot is thicker. Wings shorter, only twice as long as the width of the thorax, second cell of hind wing, as in the male, with its cross vein somewhat oblique so that the posterior lower angle is somewhat pointed. Sternite II with dense and fine, in the middle scarcer, puncturation and a few coarse shallow punctures, the following sternites finely but not so evenly punctured as, e.g., in *B. chlorotica* or *B. kohli*. Sternite II sometimes with black dot. Tergite VI black at base and with broad black median line to tip, densely punctured, sides little sinuated, but somwhat produced to apex, rounded and laterally with fine longitudinal groove on each side. Anterior metatarsus with 7-8 comb spines. Fore tarsi and tibiae yellow. Antennal 1 much longer than 3.

Length (both sexes): 10.5-14.5 mm.

Habitat : Originally described from the French Sudan this species is not rare in Egypt; it was taken at the following localities : Abu Rowash, Borgash, Kafr Hakeem, Magadla, Mansuriah, El-Katta, Giza, Meadi, Wadi Digla, Helouan, Wadi Hof, Fayoum, and at Kassassin, and also Assouan. I also saw a specimen from Konfoda (Arabia).

The insect was identified by Dr. de Beaumont.

Bembyx lusca Spinola

1812. Unnamed, Savigny, Descr. d'Egypte, pl. 16, fig. 6.
1838. *Bembex lusca* Spinola, *Ann. Soc. Ent. France*, VII, p. 467.
1893. *Bembex lusca* Handlirsch, *Sitzb. Akad. Wiss. Wien*, CII, p. 802, pl. II, fig. 13.
1951/52. *Bembix lusca* De Beaumont, *Boll. Ist. Mus. Zool. Torino*, III, p. 9.

Male : Antennae black, paler only at the apex below. Face *black*, fore angles of the clypeus and mostly sides of labrum pale. Thorax and propodeum almost

wholly black. Abdomen with pale yellow transverse bands of the tergites, and with small transverse black pairs of spots separated from dark base. Middle and hind tibiae interiorly and posteriorly lined with black. *Fore tarsi marked with black beneath.* Thorax somewhat shining, with double puncturation, finer punctures being scattered between the normal ones. Temples narrow. Apical antennal joint scarcely rounded at tip. Sternite II with median carina that is not raised to a tooth. Venter shining, sternites III-V with scarce puncturation. Mid legs simple. Antennal 3 shorter than 1. Hind wing with cross vein oblique so that its lower exterior angle is somewhat pointed. Parameres black, *truncate* at the apex, and excavated interiorly so that a rectangular tooth is formed.

FEMALE: Coloration as in the male. Tergite VI black, *without smooth medianline* almost evenly punctured, except at extreme apex where it is smoothened. Sternites shining, sternite III in basal two-thirds with fine but not very dense puncturation, otherwise smooth, with a few coarse punctures. Claws of hind leg of unequal length.

HABITAT : It is a common species distributed practically all over the country, from the Alexandria region and Mariout over the Delta and Nile valley up to Assouan.

B. lusca has never been mistaken with any other species; it is easily identified by the structure of the male genitalia, the dark colour of the antennae, the blackened under side of the fore tarsi, the oblique cross vein of the hind wing, and in the female, besides, by the evenly punctured tergite VI.

GROUP OF *B. oculata* LATR.

Bembyx oculata Latreille

1805. *Bembex oculata* Latreille, Hist. Nat., XIII, p. 301.
1893. *Bembex oculata* Handlirsch, *Sitzb. Akad. Wiss. Wien*, CII, p. 854, pl. III, fig. 5; pl. VII, fig. 31 (further references).

The Egyptian form of this variable species belongs to the ssp. *soror* Dahlbom (Hym. Eur., I, p. 489, 13; 1845). The specimens recorded from the Oasis Siwa (DE BEAUMONT, *Bull. Soc. Fouad I d'Ent.*, XXXIV, p. 9, 1950) are darker, on an average, and come very close to the ssp. of Morocco from which they are distinguished — according to DE BEAUMONT — by being somewhat larger and darker.

MALE : Antennae *black*. Face black, clypeus and labrum yellow, the former narrowly black at base, the latter seldom darkened in the middle. Thorax black, propodeum with yellow markings. The black spots on the yellow transverse fasciae of the tergites mostly separated (in the form of Siwa fused with the dark base). Venter broadly black along middle, with yellow lateral spots. Middle and hind tibiae only *interiorly* lined with black. Fore tarsi yellow.

Thorax somewhat shining, puncturation dense, but well visible. Antennal joint 3 about as long as 1, joint 12 straight at the lower margin. Sternite II in strong males with stout tooth-like carina, in weak males with low carina, though always

with small tooth apically (as against *lusca*). Venter shining, sternites III-V sparingly punctured. Mid tarsus simple. Tergite VII sinuated laterally. Cross-vein of second cell of hind wing vertical. Temples narrow. Parameres narrowly rounded at the apex (cf. HANDLIRSCH, l.c., fig. 5, pl. III).

FEMALE : Colour as in the male, the black transverse dots on tergite II always free. Tergite VI smoothened along middle, black. Sternites shining, II also at the sides so, though more densely punctured than about middle where the puncturation is rather scarce, as it is on the sternites III-V. Claws of hind legs subequal in length.

Length (both sexes) : 11-18 mm.

HABITAT : As one of the very common species *B. oculata* is widely distributed, in the Northern coastal area, the canal zone, the Delta and Nile valley to Upper Egypt; southermost record : Nag Hammadi.

The species can hardly be mistaken for another one, as *B. frey-gessneri*, similar in habitus and markings, has apart from the male characters always pale antennal joint 1. The scores of specimens of *B. oculata* I have examined vary very little as to their coloration, though they are rather variable with regard to the size of the carina of sternite II of the male.

Bembyx turca Dahlbom

1812. Unnamed, Savigny, Descr. d'Egypte, pl. 16, fig. 11.
1845. *Bembex turca* Dahlbom, Hym. Euro., I. p. 488.
1893. *Bembex turca* Handlirsch, *Sitzb. Adad. Wiss. Wien*, CII, p. 859, pl. III, fig. 7; pl. VII, fig. 33.

Characterized by the wholly or almost wholly black coloration. Fore margin of clypeus, margins of frons and temples, and, in comparatively rare cases, medially and laterally interrupted narrow transverse marks on tergites II and III yellow. Legs rather dark, tarsi dark or more or less brownish, in pale specimens the legs are yellow, but the base of the femora more or less black, the fore tibiae exteriorly, the middle tibiae on both sides and the hind tibiae interiorly and posteriorly blackened; the tarsi, excepting joint 5, blackened above. Antennal joint 1 yellow beneath, all the rest of the joints either wholly black or dull reddish beneath.

Sternites shining, II in the middle sparingly and coarsely, the following segments moderately densely punctured; tergite VI of female smoothened along the middle. Wings usually slightly shaded with grey-brown, though often hyaline. Wing venation much as in *B. oculata*.Antennal 3 about as long as 1 or little longer.

The male has an obliterate tooth on antennal joint 7, distinct teeth on joints 8 and 9; joints 10-12 are *convex* beneath and grooved, joint 13 is strongly curved. Sternite II bears a dentate carina, VI a flattened platform. The parameres are slender, narrowly rounded at tip, the aedoeagus is comparatively broad.

Length : 10.5-17 mm.

HABITAT : Common on the north-western coast *B. turca* was found eastward to the Alexandria region; it is else known westward from Egypt to Tunisia, and the south-eastern parts of Europe (Albania, Greece, Rhodes and Sarepta).

In the north-east of Egypt there exists the following form which is said to represent an eastern race :

Bembyx turca picturata Bytinski-Salz

1955. *Bembix turca* ssp. *picturata* Bytinski-Salz, *Bull. Res. Counc. Isr.*, V (1), p. 49, fig. 7i.

At first sight this form differs from *B. turca* by the pale coloration of the abdomen, the tibiae and tarsi; the latter are wholly yellow, the fore tibiae have exteriorly, the middle and hind tibiae (usually) interiorly, a short black stripe. Tergites I-V with a broad yellow transverse band (the yellow about as in *oculata*), tergite VI black or with two yellow spots. In the male the VIIth tergite is yellow at the apex, seldom almost wholly black. The sternites have in both sexes always yellow triangular lateral spots. Antennal 1 yellow, black above, flagellum dark, brownish beneath. Wings mostly more or less shaded with pale brown.

Structurally there is not much difference between *turca* and *picturata* though the 1st abdominal segment, and so the whole abdomen appears to be broader, on an average, and the denticulation of the mid femora is weaker, in *picturata*.

This form was described from Palestine and is, according to DE BEAUMONT, considered to be an eastern race of *turca*, though it has to be seen yet, whether the two forms do actually exclude themselves. If this is the case, transitions would be expected to be found in the region between Alexandria and Port Said. As a matter of fact, *picturata* is, as to its appearance, much more similar to *B. bolivari* Hdl. (from South-western Europe), differing from *picturata* by the denser puncturation of the tergites, the stouter carina on the IInd sternite, and the denser puncturation of the sternites III-V. In spite of the great similarity of the sexual organs, *picturata* appears to be specifically different from *turca*.

HABITAT : The specimens examined by me, and identified by Dr. DE BEAUMONT, are a series from Port Said (coll. Ain Shams University) and a specimen (coll. Min. Agric.) from El-Areesh in Sinai.

Bembyx frey-gessneri Morice

(Fig. 15)

1812. Unnamed, Savigny, Descr. d'Egypte, pl. 16, fig. 5 (female) ?
1897. *Bembex frey-gessneri* Morice, *Trans. Ent. Soc. London*, p. 315 (male).

MALE : 12-14.5 mm. — Vertex and frons black; orbits, clypeus, labrum and base of mandibles (broadly) yellow. Antennal joint 1 above lined with black, or with apical dot, flagellum orange, somewhat blackened above, especially at base, joint 3 yellow beneath. Thorax black, somewhat margined with yellow near wing base,

prothorax yellow, with two large black spots; scutellum posteriorly, postscutellum anteriorly, margined with yellow; propodeum black, sometimes with small yellow spot at the sides; prosternum margined with yellow, hind angles yellow; mesosternum black. Tergites of abdomen with pale greyish-yellow fasciae on segments I-V (-VI), the latter segment mostly, the VII always black. Venter black with yellow lateral spots on sternites II-V. Legs yellow, the femora posteriorly and mostly also above striped with black, the fore tibiae exteriorly, the middle tibiae posteriorly or also interiorly, the hind tibiae interiorly, with black line. Wings hyaline.

Clypeus protruding. Antennal joint 1 not enlarged, 3 little shorter than 1, joint 7 without or with indistinct, joints 8-10 with distinct, fine tooth, 11 with apical angle within, 12 at least in one direction *convex* within, 13 strongly curved, truncate or almost so, at apex. Temples quite narrow. Metatarsus I with 6 comb spines. Thorax densely punctured, distinctly so at 20 fold magnification. Tergite VII coarsely punctured, smooth along middle, little or not sinuated at the sides, almost rounded at apex. Sternite II always with black spine, VII with platform that is similarly formed as in *oculata*, the space between platform and apical margin carinated along middle, the sides of the VIIth sternite not angularly produced (as against *oculata*); sternite II coarsely punctured, the following sternites only at the sides more densely, medially very scarcely, punctured, shining. Parameres dark, at the apex within somewhat obliquely slanting. Aedoeagus strongly dilated before apex. Mid legs simple, mid femora denticulated. Wings as in *oculata*, with vein Rt 1 strongly curved inwards below, hind wings with cross vein of cell 2 curved and vertical.

Female : It is with regard to the markings of the tergites much more similar to *B. oculata* than to the male, having usually separated black spots on the tergites. The hue is more greenish, not so yellow as in *B. oculata*. Orbits mostly yellow up to the vertex, clypeus black at base. Antennae coloured as in the male. Prosternum yellow, mesosternum with yellow lateral spots. Thorax above mostly without yellow lines, but propodeum with yellow crescent spot and broadly yellow posterior angles. Postscutellum yellow, with fine black arched line. *Tibiae wholly yellow*, only the anterior tibiae sometimes with black line exteriorly; femora blackened posteriorly, the black stripe not near the fore margin, middle femora dark at base only. Tergite VI black, seldom with brownish lateral spots posteriorly, densely and coarsely punctured, smoothened along middle posteriorly. Sternites black, with yellow lateral spots on II-V, sternite II coarsely, III-V more finely and in the middle sparingly, punctured, all segments shining. Wings as in the male.

A paler coloured specimen, with U-spot on the mesonotum, yellow spots on tergite VI, wholly yellow middle femora and only at base yellow hind femora, hind margins of sternites II-V narrowly margined with yellow, I consider to be a variety rather than belonging to another similar species : v. *decipiens* nov.

Morice knew only the male of this species. Though the description given by him does not fully agree in every detail there cannot be any doubt that his specimen

is identical with the one described above, and Dr. De Beaumont agrees with my indentification. Morice compares it with *B. oculata*, and it is in fact the most similar one of those occurring in Middle Egypt. It is distinguished from *B. oculata* by the invariably pale first antennal joint, the paler, greenish-yellow colour of the abdominal fasciae, already mentioned by Morice. The male is, besides, differing by the never separated black spots of the tergites, the apically somewhat slanting margin of the parameres, the interiorly convex 12th antennal joint, the laterally not sinuated VIIth tergite and the laterally not pointed VIIth sternite. In the female, the sternites are laterally distinctly more densely punctured than in *B. oculata*, and the hind tibiae are never striped with black, interiorly.

Habitat : I examined specimens from Mansuriah, Borgash, Khatatba, Kafr Hakeem, Abu Rowash, Pyramids of Giza; Heliopolis, Meadi, Wadi Handal, and from Samalout.

Bembyx abragensis sp. n.

(Figs. 16 and 17)

Male : 13 mm. — Head black, oral margin and both orbits narrowly, and the mandibles (with red tips) yellowish; labrum dark. Antennal joint 1 and flagellum above, black, flagellum below dusky ferruginous. Thorax and propodeum without yellow markings, like the head with dense white pubescence. Abdomen black, tergites II-IV with *narrow*, medially interrupted whitish-yellow transverse bands. The whole venter black. Femora dark, fore margins yellow towards apex, fore and middle tibiae yellow, broadly dark behind, hind tibiae darkened interiorly and posteriorly. Tarsi pale. Wings slightly brownish as in *turca*.

Interior orbits almost parallel-sided, temples narrow. Antennal joints 1 and 3 scarcely differing in length, flagellum thin, dentation as in figure 17. Fore tarsi slender, metatarsus with 6 comb spines. Thorax densely punctured, not shining. Fore wing with 1st vein Rt (1st cubital) strongly bent inwards below, cross vein of 2nd cell of hind wing distinctly curved, vertical. Carina of sternite II of abdomen stout, dentiform, curved. Platform of sternite VI protruding tooth-like, in lateral aspect, triangular in dorsal view, the declivity concave. Sternite VII with three longitudinal carinae. Puncturation of sternite II coarse in the middle and irregular, of sternites III-V sparing but somewhat denser at the sides, sternite VI with somewhat finer and denser puncturation; all sternites shining. Tergite VII above sparingly, at the sides somewhat more densely punctured; the lateral margin first convex, then sinuated, the apical margin slightly excavated. Parameres (Fig. 16) very slender, narrowly rounded at the apex and quite indistinctly somewhat oblique within; aedoeagus *broad*, bipartite at the apex, with pointed and curved upper, and rounded lower part; volsella very slender.

Female : 13.5-14.5 mm. — Black, the fore margin of the clypeus (broadly), labrum and orbits yellow. Antennal joint 1 below yellow or dark, flagellum ferruginous, much blackened above. Prothorax black, margined with yellow. Mesothorax

and propodeum black, scutellum margined with yellow. Tergite I of abdomen at base broadly, at apical margin narrowly, black, with pale yellow transverse band that is narrowed about the middle, tergites II-V with yellow transverse bands and dark spots that are (probably always) fused with the dark base; tergite VI black. Under side black, only the humeral calli and small lateral spots on tergites II-V, yellow. Femora for the major part black, tibiae either wholly yellow and only the fore tibiae with black line exteriorly, or middle and hind tibiae interiorly and exteriorly with ill-limited brown lines.

Antennal 3 somewhat longer than 1. Temples narrow. Fore tarsi with 6 comb spines on the metatarsus. Puncturation of the thorax as in *oculata*. Tergites VI smoothened along middle. Sternites shining, II densely punctured laterally, yet slightly shining, sternites IV and V at base more finely and densely punctured than posteriorly, much as in *frey-gessneri*, not smooth as in *oculata*. Venation as in the male.

HABITAT : Females from Wadi Abrag (South Eastern Desert), iii, 1928 and 1942; 1 male, Gebel Elba, Wadi Kansisrob, 27. xii. 1938 (coll. Ministry of Agriculture).

This species much resembles *B. frey-gessneri*, but differs in the female by the dark propodeum, the fused spots on tergite II and the dark femora; the male, too, is much darker, and the parameres are less blunt at the apex. Since *B. frey-gessneri* is widely distributed, occurring at the Red Sea coast and the Hedjas, too, it is unlikely that our species represents a race of *B. frey-gessneri*. The male, which I should have put aside until further material would be available, does, according to the opinion of Dr. DE BEAUMONT, fit well to the female described above. Exteriorly this species much resembles the South African *B. forcipata* Hdl. which, however, belongs to the *melanopa*-group, differing much in the shape of the male genitalia.

Bembyx melanura Morawitz

(Figs. 18 and 19)

1888. *Bembex melanura* Morawitz, *Horae Soc. Ent. Ross.*, XXIII, p. 141 (male).
1893. *Bembex melanura* Handlirsch, *Sitz. Akad. Wiss. Wien*, CII, p. 858, pl. III, fig. 6; pl. VII, fig. 32.

MALE : Head pale yellow, only the vertex with dark circular spot. Antennal 1 pale orange, above with black dot, flagellum ferruginous, darkened above. Thorax black above, yellow laterally and posteriorly, with fine yellow U-shaped spot. Sterna yellow, with black lateral spots. Scutellum broadly margined with yellow posteriorly, propodeum with profuse yellow design, and rather dense pale pubescence. Femora close to upper margin, tibiae interiorly, with black line, tarsi pale. Abdomen pale greenish yellow, the margins of the black spots on 1st and IInd tergites yellow. The pale fasciae broad, tergite I at base and hind margin black with two roundish black spots fused with the fore margin; tergite II like the following tergites narrowly black at the posterior margin, II with two transverse spots; tergite VII black, shining, with only a few coarse punctures. Sternites anteriorly predominantly yellow, the

posterior ones mainly black; sternite II yellow with black median spot; yellow fasciae are full on II, interrupted on III and IV.

Antennal joint 1 *distinctly thickened*, 9-11 with small tooth, 12 *convex* interiorly, sulcate, 13 much excavated interiorly, slender, rounded-truncate at tip. Fore tarsi slender, metatarsus with 6 comb spines. Middle femora rather evenly denticulated, legs otherwise simple. Carinated spine on sternite II present, usually lined with black above, VI with normal platform, VII with two strongly approximated sharp carinae and between them an indistinct carina. Sternite II densely punctured and pubescent, behind spine almost smooth, sining, the following sternites almost bare in the middle. Parameres rather slender, rounded at tips (Fig. 18). Wings hyaline, Rt 1 of fore wing strongly curved inward below, cross vein of 2nd cell of hind wing vertical.

Female : Wing length 9-10 mm. Coloration as indicated for the male, though much varying on the venter, the darkest specimens having only the sides of the sternites yellow, always with a large yellow spot on sternite II posteriorly on either side, the palest having sternites I-III wholly yellow. Clypeus either yellow or narrowly black at base. Antennal 3 about as long as 1. Under side of thorax either wholly yellow or with more or less large black spot. Tergite VI black or with yellow apex, median line smoothened, sides only very slightly sinuated. Temples very slightly widened downwards. Metatarsus I with 6 comb spines. Sternite II very sparingly punctured in the middle, densely punctured at the extreme sides, the remaining sternites very sparingly punctured, almost smooth in the middle.

Length (male and female): 13.5-14.5. mm.

In coloration and habitus, and also in the structure of the male antennae this species very much reminds of *frey-gessneri*, but differs by the paler venter, the greater similarity between male and female, the presence of a dark line on the hind tibiae, also in the palest specimens, *within*, the enlarged 1st antennal joint of the male and the shape of the parameres; the bases of the sternites III-V are more distinctly punctured at base, in *frey-gessneri*.

Habitat : Most of the specimens I saw were collected at Mersa Matrouh in August (coll. Cairo Univ. and Ain Shams Univ.); in the collection of the Ministry of Agriculture there is a specimen from Heliopolis and another one from the Wadi Handal, both taken in July.

I am identifying the above described species with Morawitz's *melanura*, agreeing with de Beaumont's opinion, although a direct comparison with typical specimens (from south-eastern Russia and Mongolia) will be necessary for confirmation. The species is, in any case, new for Egypt.

Bembyx radoszkowskyi Handlirsch

1893. *Bembex radoszkowskyi* Handlirsch, *Sitzb. Akad. Wiss. Wien*, CII, p. 865, pl. III, fig. 11; pl. VII, fig. 36.
1949. *Bembex radoszkowskyi* De Beaumont, *Bull. Soc. Sci. Nat. Maroc*, XXIX, p. 274.

Male : 12-14 mm. — Face with orbits yellow, with long white pubescence.

Antennal joint 1 yellow or with black line dorsally, flagellum ferruginous below, black above. Prothorax almost wholly yellow, mesothorax black, sides margined with yellow, sometimes with yellow dorsal lines, seldom with full U-shaped spot; scutellum laterally and posteriorly broadly yellow, postscutellum yellow with transverse, arched, black line. Propodeum black with medially sometimes interrupted yellow crescent, posteriorly at the angles with large yellow spot. Abdomen with *broad*, not or scarcely sinuated yellow transverse fasciae, without black dots or with small, free or fused, dots on tergite II; colour of these bands yellow, not greenish- or greyish-yellow. Under side : prosternum in the middle and mesosternum black, with narrow anterior and lateral spot, or with only the latter. Sternites yellow, I little marked with black, II with black median spot or with black cross-band connected with the black basal band of the tergite; sternites III-VI blackened at the *middle* of the base. Tergite VII more or less broadly black at base, and yellow to ferruginous at the apex. *Legs wholly yellow*, only the trochanters with black dots.

Labrum short, clypeus strongly protruding. Temples narrow. Antennae not enlarged towards apex, tooth on joint 7 very small, 8 with two such teeth, 9 and 10 distinctly dentate, 12 straight within or slightly concave, 13 slightly curved, rounded at tip. Mesonotum somewhat shining, puncturation distinctly visible at 10-fold magnification. Middle femora denticulated. Middle tibiae without apical spine, metatarsus very slightly concave within, and with slight convexity beyond base. Metatarsus I with 6 comb spines. Tergite VII simple, rounded at apex, dorsum with puncturation scarce apically. Venter shining, sternite II densely punctured at the sides, nearly dull, more coarsely and scarcely punctured in the middle, with hook-like tooth, sternite VI with platform flattened or only with transverse convexity, *without carina*. Sternite VII narrow, with two converging furrows. Parameres slender, straight at the exterior, slightly convex at the interior margin, concave before middle so that they appear slightly sole-shaped, apex narrowly rounded, brownish. Wings hyaline, venation about as in *B. oculata*.

Female : 12 mm. — Coloration as in the male. Abdominal tergite II without blanck dots. Antennal joint 3 as long as 1. Sternite II with black post-basal cross-band, very *coarsely and longitudinally rugosely punctured in the middle*, more finely and very densely punctured at the sides, dull, with weak longitudinal carina, particularly at the base. Venter shining, sternites III-VI with scarce, coarse puncturation. Tergite VI yellow, almost everywhere densely punctured, with a somewhat transparent apical margin.

A single specimen (Kerdasa, 17.v.1913) of Alfieri's collection seems to be not specifically different, though it is much larger (14-15 mm.), has a large black almost W-shaped spot on sternite II and broadly black bases of the following segments (III-V) and a broad U-spot on the mesonotum.

Habitat : I have seen specimens from Kafr Hakeem, Hawamdiah, the Pyramids of Giza, Sakkara, from Meadi and Turrah (v-ix).

Identification confirmed by Dr. de Beaumont.

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ADDENDUM

After the conclusion of this paper Dr. J. DE BEAUMONT informed me that according to his latest studies the species described in this paper under the name of *turca* Dhlb is not identical with the typical *turca* (from the Balkans and Rhodes), but represents the darkest sub-species of *B. flavescens* Sm. (typical form from the Canary Islands) and will receive a new name. *B. picturata* BytS. and *B. bolivari* Hdl. are other sub-species belonging to *B. flavescens* Sm.

THE EXTERNAL MORPHOLOGY OF THE ADULT *RHYNCOLUS CYLINDRICUS* BOH., WITH A DETAILED STUDY OF THE ANATOMY AND HISTOLOGY OF ITS ALIMENTARY CANAL

[*Coleoptera* : *Curculionidae*]

(with 58 Text-Figures)

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I. INTRODUCTION

The species belonging to the genus *Rhyncolus* cause serious injury to wood. BRITTON (1939) reported *Rhyncolus ulkei* Horn reducing the inside of the woodwork and stairs of a basement to a fine powder. Investigations carried out by PARFENT'EV (1938) in a number of towns and villages of the Volga, revealed that the timber of about 60% of all the buildings was damaged by *Rhyncolus culinaris* Germ. Damage done by *Rhyncolus* has also been reported by DOANE, VAN DYKE, CHAMBERLIN, and BURKE, in 1936, while HAMMAD (1955) gave the description of the larva of *Rhyncolus cylindricus* Boh. (nec *cylindrus*).

In Egypt, adults and larvae of *Rhyncolus cylindricus* Boh. occasionally infest poplar (*Populus* sp.) and willow (*Salix* sp.). They mine through the stems and branches eating out their inside wood which is eventually converted into a powdery mass. In heavy infestations, the branches frequently break and the trees finally decay.

In spite of their economic importance, no much work has been done on the morphology and anatomy of this weevil. In fact, little morphological work has been carried out on the adult Curculionidae. Therefore, it was thought advisable to attempt elucidating some of the morphological and anatomical features of the adult fo *Rhyncolus cylindricus* Boh., as a representative of a genus that lacks such information.

II. MATERIAL AND TECHNIQUE

Adults *Rhyncolus cylindricus* Boh. used in this work were obtained from decayed poplar and willow trees found at Moharram Bey district, in the south-east region of Alexandria, Egypt. They were killed in 50% alcohol and slides were prepared of all the component parts of the body by the usual method of boiling in potash, dehydrating, clearing in xylol or clove oil, and mounting in Canada balsam.

For sectioning, the adults were starved for 10-15 days, fixed in alcoholic BOUIN, dehydrated, and then transferred to terpenol for 2-3 weeks, which was followed by three changes of chloroform before embedding in wax. Serial cross and longitudinal sections of the adult as a whole were then stained with EHRLICH's haematoxylin and counter-stained in eosin.

In search for bacteria and protozoa, the mid-gut as well as the mycetomes were smeared over glass slides, fixed by heat, and then stained with LOFFLLER's methylene blue for 3 minutes.

III. EXTERNAL MORPHOLOGY

1. Head and appendages

Head capsule

The head of the adult *Rhyncolus cylindricus* Boh. (Figs. 1 and 2) is oblong and rather flattened dorso-ventrally. It is prolonged anteriorly into a rostrum the length of which is about the same as that of the head capsule. The rostrum is slender, cylindrical in shape, with parallel sides, and sculptured. In the female the rostrum is sometimes thinner, longer, and more curved than that of the male. The rostrum has on either side a groove for the reception of the antennal scape. The head is well sclerotized and its sclerites are fused, the sutures being incomplete or vestigia l.

The epicranial suture is obliterated and is represented only by the anterior portions of the epicranial arms (Figs. 1 and 3, *ea*), the epicranial stem being totally absent. Each epicranial arm (Fig. 3, *ea*) extends from the anterior margin of the rostrum and ends at an internal process, which serves for the dorsal articulation of the mandibles. Behind this process, the anterior tentorial pit is located (Fig. 3, *at*).

The ante-clypeus (Fig. 3, *aclp*) is a well-defined sclerite at the apex of the rostrum. Its anterior margin is smooth and strongly curved inwards medially forming a bilobed structure. The posterior margin, which also marks the anterior border of

the post-clypeus, is only slightly curved inwards, but finely corrugated and fringed with ten stout setae. The arrangement of these setae is peculiar. There are two long setae in the middle with four shorter ones on either side. The post-clypeus (Figs. 1 and 3, *ep*), is represented by a smooth area surrounded by a faint suture (*es*).

The frons (Figs. 1 and 3, *fr*) is represented by the slightly convex area limited anteriorly with the faint suture (*es*), while posteriorly it is fused with the vertex.

The vertex (Fig. 1, *vr*) is an extensive area, slightly convex and is prolonged anteriorly with the frons to form the roof of the rostrum. The hypostoma is obscurely defined externally but is represented by three different structures : the thickened declivous anterior margin of the ventral wall of the rostrum, the sides of the submentum, and a somewhat irregular apodeme (Fig. 2, *hsta*). It is composed of the median indistinct pregula (Fig. 2, *pgu*) and the lateral pregenae. The pleurostoma (Fig. 2, *plst*) is represented by the convex area surrounding the large mandibular scrobe. The broad area between the occipital foramen (Fig. 2, *for*) and the submentum (Fig. 2, *smt*) is sometimes designated as the gula. In *Rhyncolus cylindricus* Boh., the gula is not represented, and there is but a single median gular suture (Fig. 2, *gus*) in the ventral surface of the cranium. The pre-gula is represented by a deep concave median area (Fig. 2, *pgu*).

The occipital foramen (Fig. 2, *for*) is a triangular opening with rounded angles.

The submentum (Fig. 2, *smt*) lies as a distinct sclerite in front of the occipital foramen. Its apex is truncate and supports the labium. The gena (Fig. 2, *ge*) forms the whole of the lateral area below and posterior each compound eye. The genae are not defined. The only distinct limit is the gular suture, where the genae meet in the mid-ventral line. The genae are broad owing to their lateral and anterior extension. They extend anteriorly till the hypostomal area forming laterally the pregenae (Fig. 2, *prge*).

Ventrally, on either side of the rostrum and about its middle, there is a groove or scrobe (Fig. 2, *asc*) for the reception of the scape of the antenna.

Mouth-parts

The mouth-parts of *Rhyncolus cylindricus* Boh. are of the typical chewing type. All the usual parts are present except the labrum which is wanting.

The mandibles (Figs. 4-8) in both sexes are stout, strong, triangular and heavily sclerotized structures. When at rest they are partly concealed under the anteclypeal region. The right and the left mandibles are more or less equal in size, but the former is slightly elongated. Each mandible has the inner face (Figs. 4 and 5) roughly plane and bearing scars, while the outer face (Figs. 6 and 7) is slightly convex and devoid of any scars. On the anterior margin of the mandible there are prominent teeth and on its ventral surface there are two short, stout setae (Figs. 4 and 5). The pharyngeal bracon is about twice as long as the mandible itself (Fig. 8, *phbr*). It is a long, slender, sclerotized structure lying free in the pharynx. Medially, the bracon is attached to the postero-ventral angle of the mandible, behind the molar

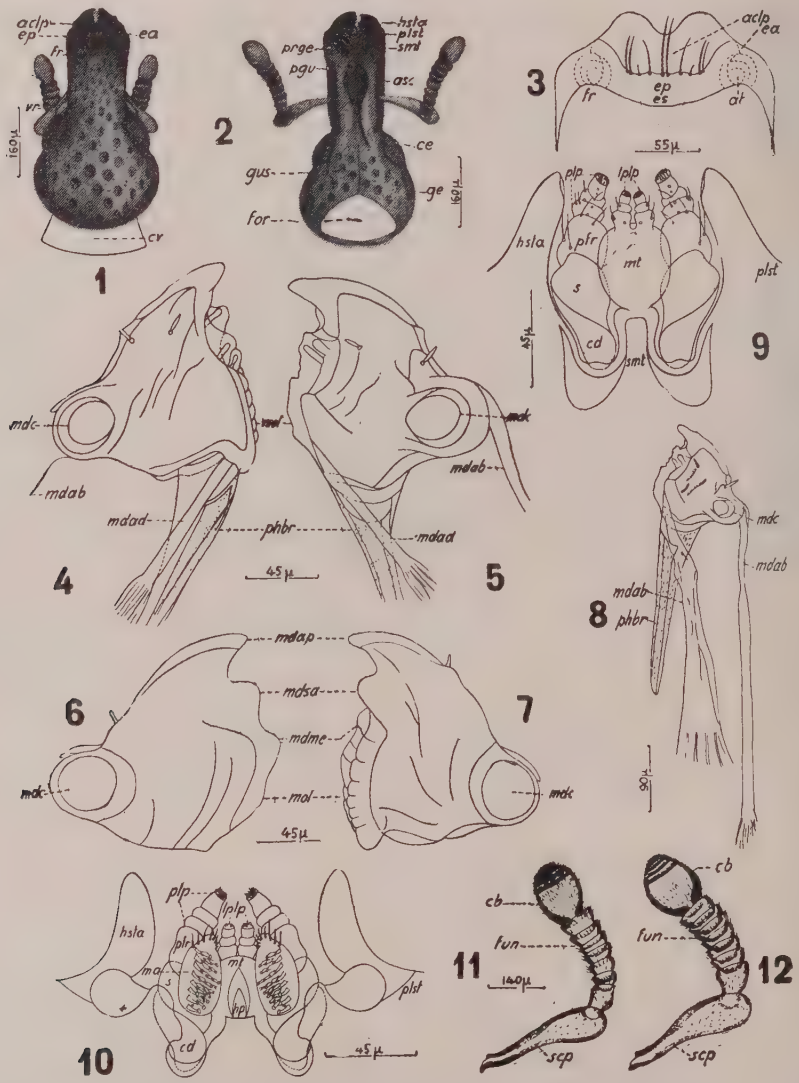

FIG. 1: The head capsule, dorsal aspect (*aclp*, ante-clypeus; *cv*, cervicum; *ea*, epicranial arms; *ep*, epistoma; *fr*, frons; *vr*, vertex). — FIG. 2: The head capsule, ventral aspect (*asc*, antennal scrobe; *ce*, compound eyes; *for*, occipital foramen; *ge*, gena; *gus*, gular suture; *hsta*, hypostomal apodeme; *pgu*, pregula; *plst*, pleurostoma; *prge*, pregenae; *smt*, submentum). — FIG. 3: The anterior part of the head-capsule, dorsal aspect (*aclp*, ante-clypeus; *at*, anterior tentorial pit; *ea*, epicranial arms; *ep*, epistome; *es*, a faint suture; *fr*, frons). — FIG. 4: The right mandible, ventral aspect (*mdad*, mandibular tendons; *mdc*, mandibular condyle; *mol*, molar part; *phbr*, pharyngeal bracon). — FIG. 5: The left mandible, ventral aspect (*mdad*, mandibular tendons; *mdc*, mandibular condyle; *mol*, molar part; *phbr*, pharyngeal bracon). — FIG. 6 : The left mandible, dorsal aspect (*mdc*, mandibular condyle; *mdsa*, mandibular teeth; *mol*, molar part). — FIG. 7: The right mandible,

dorsal aspect (*mdc*, mandibular condyle; *mdsa*, mandibular teeth; *mol*, molar part). — FIG. 8: The left mandible, ventral aspect (*mdad*, mandibular tendons; *mdc*, mandibular condyle; *phbr*, pharyngeal bracon). — FIG. 9: The labium, outer surface (*cd*, cardo; *hsta*, hypostomal apodeme; *lplp* labial palpus; *mt*, mentum; *pfr*, palpifer; *plp*, maxillary palpus; *plst*, pleurostoma; *s*, stipes; *smt*, submentum). — FIG. 10: The labium, inner surface (*cd*, cardo; *hp*, hypopharynx; *hsta*, hypostomal apodeme; *lplp*, labial palpus; *ma*, mala; *mt*, mentum; *pfr*, palpifer; *plp*, maxillary palpus; *plst*, pleurostoma; *s*, stipes). — FIG. 11: Antenna of the female (*cb*, club; *fun*, funiculus; *scp*, scape). — FIG. 12 : Antenna of the male (*cb*, club; *fun*, funiculus; *scp*, scape).

part. Its base is markedly concave, wrapping round the tendon of the mandibular adductor muscle (Fig. 8, *md. ad*). The bracon tapers gradually towards its distal end and its surface is densely armed with short slender spines. On the inner side, each mandible bears three prominent teeth, the most apical tooth being the largest and the lower the smallest (Figs. 6 and 7, *md. ap*, *md. sa*, *md. me*). In the right mandible the molar part (*mol*) is strongly convex and coarsely serrated (Figs. 4 and 7), while it is stout, blunt and smooth in the left one (Figs. 5 and 6).

The articulation of each mandible with the rostral tip is effected by a pair of condyles (Fig. 8, *md. c*). The mandibular condyle is received by an acetabulum excaved in the dorsal surface of the tip of the pregena, the margin of this acetabulum is infolded around the neck of the condyle. It is apparent that this arrangement of condyles and acetabula gives the articulation of the mandibles great rigidity in planes outside that of its rotation. Each mandible is moved by a large adductor (Fig. 8, *md. ab*) and a smaller adductor (*md. ad*) muscles inserted on mandibular tendons.

In the maxilla, the cardo (Figs. 9-10, *cd*) is stout and triangular in shape, and articulates with the hypostomal apodeme (Fig. 9, *hsta*).

The stipes (*s*) is clearly defined as a sub-basal sclerite articulating with the cardo and joining to the palpifer and mala by distinct sutures. It is a rectangular sclerite with the anterior limit parallel to the wider posterior margin. From the outer surface (Fig. 9, *s*) a very small area of the stipes is concealed by the mentum. From the inner surface (Fig. 10, *s*) about three quarters of the stipes are concealed under the palpifer (*pfr*) and the mala. The stipes bears no setae.

The maxillary palpifer (*pfr*) is a large rectangular and stout sclerite. Its size is equal to that of the stipes but much longer than the palpus (*plp*). It is separated from the mala and the stipes by distinct sutures and resembles a very large basal joint of the palpus. Disto-laterally, it bears two long setae which are as long as the first two segments of the palpus. Its anterior limit also bears two smaller setae. From the inner side, half of the palpifer's area is concealed under the mala. The palpifer supports the maxillary palpus.

The maxillary palpus (*plp*) is stout, conical and three-segmented. It is shorter than the palpifer. The segments differ in size and length. The first and the second segments are equal in length, but the former is broader. The third or apical segment is the longest and narrowest. It has a circular tip which is inclined inwards and bear-

ing cone-like structures which are probably sense-organs. On the three segments there are some sensillae and short setae.

The sub-galea, galea and lacinia are all represented by a simple big rectangular lobe without any indication of sutures. This lobe is known as the mala (Fig. 10, *ma*). The length of the mala nearly equals the length of both the stipes and palpifer. The interno-lateral face of the mala is armed with stout lacinial setae, while the externo-lateral face bears no setae. The anterior margin of the mala extends forward forming a small rounded process which bears some setae of different length.

The labium (Figs. 9 and 10) is a large and well-developed sclerite. It is better seen from the outer surface than from the inner.

The submentum (*smt*), or the gula peduncle of HOPKINS (1911), is a solid individual sclerite. It fuses entirely with the ventral wall of the rostrum and no distinct suture marks its posterior limit. It is also fused with the pre-gula. Its apex is truncate and supports the mentum and the other parts of the labium.

The mentum (*mt*) is a very large, single and circular sclerite. It can be seen easily from the outer surface, concealing a small area of the stipes and the palpifers. From the inner surface, it is hidden under the mala, the stipes, and the palpifers and, therefore, only a small part of the mentum could be seen. Both surfaces do not bear any setae.

The labial palpifer is not defined, but is represented by the anterior area of the mentum. The labial palpus (*lplp*) could be seen from the outer and the inner surfaces. It is three-jointed, stout, conical, and with some setae and sensillae on its surface. The basal joint is the longest and the largest, while the third is the smallest. The labial palpus has a membranous tip inclined inwards and bearing few cone-like structures which are possibly sense organs.

The hypopharynx (*hp*) is a small lobe on the dorsal side of the posterior margin of the mentum.

Compound eyes

The compound eyes are located antero-laterally on the head, posterior to the antennal groove. They are somewhat larger in the male than in the female.

Antennae

The antennae are carried ventrally on the rostrum which has a groove on either side for the reception of the antennal scape (Fig. 2, *asc*). In the female (Fig. 11), the antenna is slightly thinner and longer than that of the male (Fig. 12).

The scape (*scp*) is slightly shorter than the funiculus and is rounded distally. At the base of the scape there is a small process lying in the antennal socket.

The funiculus (*fun*) is seven-jointed, the first or basal joint being about twice as long as each of the following segments, which are of about the same length. Segments 2 to 7 increase gradually in width towards the club. Sense setae are dispersed all over the joints. On each joint long hairs also are found.

The club (*cb*) is ovate, with a rounded apex and with five obscurely-defined joints. The first joint forms the greater part of the club, and is clothed with short hairs and long bristles. The other joints are about as equal in length and are densely clothed with fine hairs.

If the head is fully stretched, a short membranous region, the neck or cervicum (Fig. 1, *cv*), becomes apparent. No cervical sclerites are present.

2. Thorax and appendages'

The thorax, slightly exceeds the abdomen in length. The prothorax articulates freely with the mesothorax, but the latter and the metathorax are firmly connected to each other.

The protergum is slightly longer than both the meso- and metatergum together. The prosternum is much longer than the mesosternum and is about as equal as the metasternum. The thoracic pleura show the same relative proportions as the sterna.

Prothorax

The prothorax (Figs. 13 and 14) exceeds in size any other body segments whether thoracic or abdominal. Posteriorly, it is wider than in front so that the posterior foramen is somewhat wider than the anterior one. The margins of both foramina are serrated and armed with fine hairs. The dorsal area is somewhat larger than the sternal and consequently both foramina could be easily seen from the ventral aspect (Fig. 14).

The protergum is composed of one large sclerite, the pronotum (*pn*), occupying whole of the dorsal surface of the prothorax. It is more or less convex, longer than broad, and full of round sculptures from each of which arise two short hairs. Its posterior bisinuate margin is broader than the inwardly curved anterior margin.

The propleuron is indistinct because of the lateral extension of the pronotum and the absence of any pleurodorsal suture. A slight elevation from the sternum (Fig. 14) differentiates the latter from the propleuron.

The episternum (Fig. 14, *eps*) occupies the lateral area of the ventral surface of the prothorax. It falls within a level different from that of the epimeron or the sternum. It extends from the anterior foramen antero-laterally to the pleural suture which is very short and separates the episternum (*eps*) from the much smaller epimeron (*epm*). This pleural suture extends between the fore-coxal cavity and the outer portion of the posterior margin of the ventral wall.

The epimeron (Fig. 14, *epm*) is a low levelled sclerite extending laterally, but is elevated posteriorly. It is somewhat more sclerotized than the episternum. It occupies a small portion of the ventral region of the prothorax.

The prsternum (Fig. 14) occupies the major portion of the ventral area which is comparatively smaller than the dorsal one. It is convex, with its anterior margin slightly curved inwards and the posterior margin greatly bisinu .te.

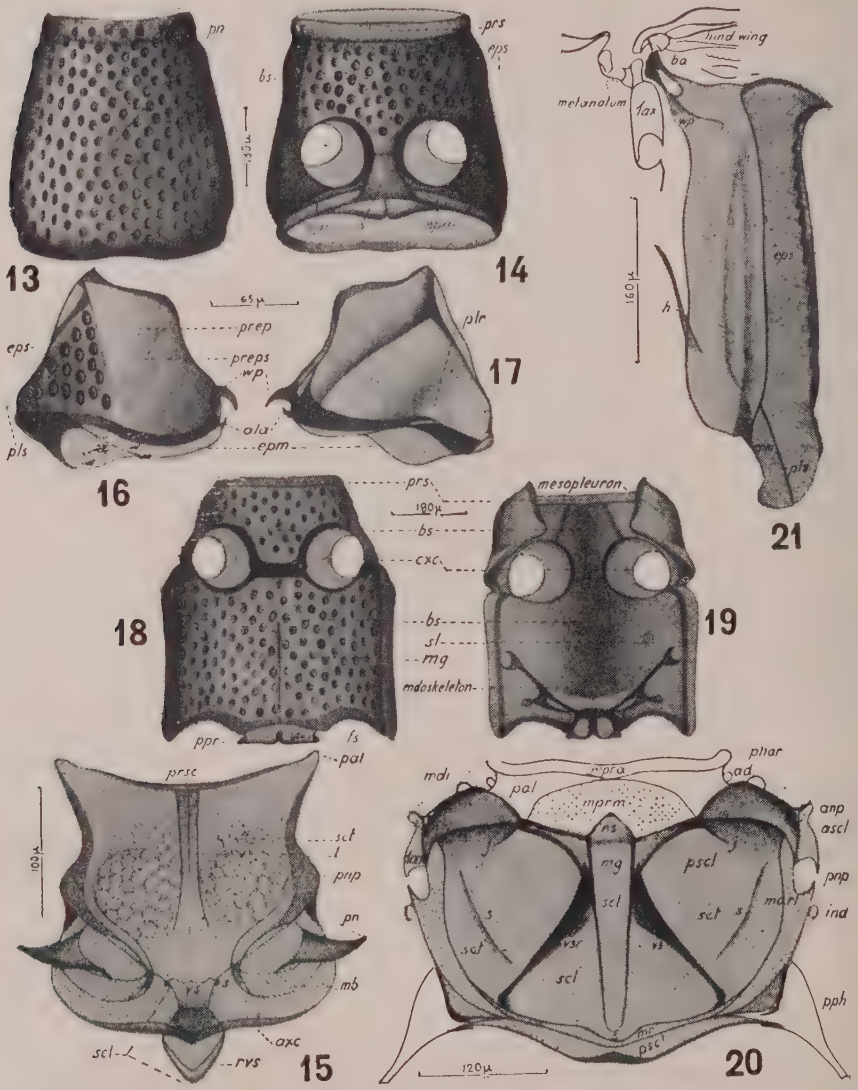

FIG. 13: Prothorax, dorsal aspect (*pn*, pronotum). — FIG. 14 : Prothorax, ventral aspect (*bs*, basisternum; *cxc*, coxal cavity; *epm*, epimeron; *eps*, pleural suture; *prs*, presternum; *s*, sternellum). — FIG. 15 : The mesotergum (*axc*, axillary cord; *l*, longitudinal median suture; *mb*, low-levelled membranous area; *pal*, antero-lateral projection; *pn*, sclerotized plate; *pnp* posterior wing process; *prsc*, prescutum; *rvs*, reversed notal suture; *s*, triangular plate; *scl*, scutellum; *sct*, scutum; *vs*, scuto-scutellar suture). — FIG. 16 : The mesopleuron, dorsal aspect (*ala*, alar apophysis; *epm*, epimeron; *eps*, episternum; *pls*, pleural suture; *prep*, pre-episternum; *preps*, pre-episternal suture; *wp*, pleural wing process). — FIG. 17 : The mesopleuron, ventral aspect (*ala*, alar apophysis; *epm*, epimeron; *plr*, pleural ridge; *wp*, pleural wing process). — FIG. 18: The meso- and metasternum;

outer view (*bs*, basisternum; *cxc*, coxal cavity; *fs*, furca-sternum; *mg*, median groove; *ppr*, posterior projections; *prs*, presternum). — FIG. 19: The meso- and metasternum, inner view (*bs*, basisternum; *cxc*, coxal cavity; *prs*, presternum; *s*, suture; *sl*, sternellum). — FIG. 20: The metatergum (*ad*, Hopkins' second structure; *anp*, anterior notal process; *ascl*, antero-lateral lobe; *1ax*, first axillary sclerite; *j*, intra-scutal suture; *marl*, lateral invaginated scutal lobe; *mdi*, Crampton's first structure; *mg*, median groove; *mpra*, median prescutal area; *mprm*, median prescutal membrane; *mr*, median ridge; *ns*, transverse anterior suture; *pal*, pre-alare; *phar*, antero-lateral sclerotized arm; *pnp* posterior notal process; *pph*, post-phragma; *pscl*, post-scutellum; *s*, intra-scutal suture; *scl*, scutellum; *sct*, scutum; *vs*, scuto-scutellar suture; *vsr*, triangular internal ridge). — FIG. 21 : The metapleuron (*1ax*, first axillary sclerite; *ba*, basalare; *epm*, epimeron; *eps*, episternum; *h*, metapleural hook; *pls*, pleural suture; *wp*, pleural wing process).

The presternum (*prs*) is a band-like area existing along the anterior margin of the ventral view. It is narrow and comparatively more sclerotized than the other parts.

The basisternum (*bs*) is represented by the median area of the ventral view. It is the largest prosternal sclerite and is somewhat convex. Its posterior section terminates in an acute point between the coxal cavities.

The sternellum (*s*) is represented by a posterior and median area situated anteriorly between the fore-coxal cavities (*cxc*) and posteriorly between the inner epimeral ends. It is more or less triangular in shape, with the anterior apex truncate and the posterior margin slightly convex. The coxal cavities are large, and there are no spiracles in the prothorax.

Mesothorax

The mesothorax is short and partially hidden, partly by the prothorax which covers the anterior third of its sternites, pleurites and tergites, and partly by the bases of the elytra which cover the posterior area of the tergites leaving only the scutellum exposed.

The mesotergum (Fig. 15) is triangular in shape and can be seen after removing both the elytra and the prothorax. It is less sclerotized than the protergum but more so than the metatergum.

The prescutum (*prsc*) is clearly defined as a convex sclerotized plate. It lies in a level lower than that of the scutum (*sct*) which occupies two-thirds of the mesotergal area situated between the median process of the scutellum (*scl*) and the posterior limit of the prescutum (*prsc*). It is cup-shaped with antero-lateral projection (*pal*). Its lateral margin is slightly concave and ends posteriorly with a somewhat large, rounded, and sclerotized projection representing the posterior wing process (*pnp*). The postero-lateral limits of the scutum are so inclined that the width of its posterior margin is about one-third of the anterior margin. The posterior limit of the scutum is the wavy scuto-scutellar suture (*vs*) which demarks the scutum anteriorly from the scutellum (*scl*) posteriorly. The scutum is divided into two equal parts by a longitudinal median suture (*i*) which extends throughout its length. On each side of this longitudinal medial suture there is a longitudinal sclerotized part which demarks an internal ridge.

The scutellum (*scl*) is spoon-shaped and about one-third of the scutum (*sct*). Its anterior limit is the scuto-scutellar suture (*vs*). A suture, or the reversed notal suture (*rvs*), runs parallel to the posterior marginal rim of the spoon. The concave anterior part of the scutellum is lower-levelled than both the scutum and the posterior scutellar region. It is distinctly elevated and lying exposed between the basal portions of the closed elytra. It overlaps the anterior median metatergal area when the elytra are removed.

A low-levelled membranous area (*mb*) exists on either side of the anterior portion of the scutellum (*scl*) and is attached to the lateral margin of the scutellum by a small sclerotized and triangular plate (*s*).

Posteriorly, there is a fairly sclerotized marginal band-like structure (*axc*) on each side of the scutellum. These two band-like structures meet and fuse with each other forming underneath the scutellum, an internal ridge, known as the axillary cord.

The post-scutellum of the mesotergum is provided with two small fairly sclerotized plates (*pst*) which probably represent the post-scutellum. These plates are connected to the metanotum as will be seen later.

The mesopleuron (Figs. 16 and 17) is strongly sclerotized and the greater part of it is lying dorsally. It is divided by the pleural suture (*pls*), which run sparallel to its anterior margin, into a larger anterior episternum (*eps*) and a smaller posterior epimeron (*epm*).

The pre-episternum (Fig. 16, *prep*) is nearly as large as the episternum proper. It is sclerotized, sculptured and separated from the episternum proper by an incomplete suture, the pre-episternal suture (*preps*). Furthermore, it is narrow near the sternum and gradually broadens towards its end, while its anterior margin is strongly ridged internally.

The episternum proper (*eps*) is a triangular area constituting the major part of the mesopleuron. Its front region is less sclerotized than the posterior one. It is separated from the epimeron (*epm*) by the pleural suture which is the external manifestation of the pleural ridge (Fig. 17, *plr*). The apex of its dorsally extended part (Fig. 16) is concave and carries two apodemal processes. The dorsal porcess is the pleural wing process (*wp*) which supports the elytron. The other apodemal process, or the alar apophysis (*ala*), is attached to the mesotergum by means of a ligament.

The epimeron (Figs. 16 and 17, *epm*) is nearly triangular in form and is situated posteriorly to the episternum, from which it is separated by the pleural suture (*pls*). It is divided into two parts, a lateral sclerotized part and a semi-membranous one, and lies in a level different to that of the episternum.

The mesosternum (Figs. 18 and 19) is a crown-shaped immovable structure. Its posterier margin enters into the formation of the middle coxal cavities (*cxc*). It is firmly attached to the metasternum, and the inter-coxal piece is elevated and truncate at apex. Its lateral margins diverge as they proceed posteriorly. Since the

sternellum and the post-sternellum are not represented by external distinct areas, the mesosternum only consists of a presternum and a basisternum.

The presternum (*prs*) is represented by a narrow band-like marginal sclerite located along the anterior straight margin of the mesosternum.

The basisternum (*bs*) constitutes the major area of the mesosternum; its lateral margins are diverging towards the posterior end. It is somewhat convex and sculptured. The area of the basisternum, which extends between the coxal cavities, is more sclerotized than the rest of the mesosternum.

A narrow deeply sclerotized area of the coxal cavity (*cxc*) is present. There are also two mesothoracic spiracles located in the inter-segmental membrane adjacent ot the lateral region of the epimeron.

Metathorax

The metatergum (Fig. 20) is entirely concealed by the elytra when at rest. It is shorter than broad, and larger in area than the mesonotum, but smaller than the protergum. It differs from the protergum and the mesotergum in being composed of more or less membranous sclerites differentiated by more sclerotized limits. It is slightly convex and is pushed in front so that its caudal margin becomes dorsal to nearly the middle metasternal region.

The prescutum is well developed and occupies a comparatively large area along the front meta-tergal margin. It includes : (1) a median prescutal area (*mpra*) which is broad and short and occupy the anterior median region of the metatergum, and has two antero-lateral sclerotized arms (*phar*) which taper distally and run parallel with the meso-postscutellar plates (Fig. 15, *pn*) to which they are finally connected by their ends; (2) the pre-alare (Fig. 20, *pal*), which consists of two separate areas lying postero-lateral to the median prescutal membrane (*mprm*), and which is roughly trapezoidal and fairly sclerotized; (3) a median prescutal membrane (*mprn*), which lies behind the median prescutal area and connects the latter with the scuto-scutellar region of the metatergum; (4) a lateral prescutal membrane stretching between the antero-lateral sclerotized arm (*phar*) and the anterior notal process (*anp*). The anterior notal process (*anp*) to which the first axillary sclerite (*1ax*) articulates, lies at the antero-lateral angle of the metatergum.

The scutum (*sct*) is represented by the two areas lying lateral to the median groove and the oblique scuto-scutellar suture (*vs*). Internally, the scuto-scutellar suture is produced into a broad ridge or the scuto-scutellar ridge entodorsum. Each part of the scutum is subdivided by two intra-scutal sutures (*js*) into three smaller sclerites. The nearly transverse suture (*j*) runs postero-laterally, thus differentiating an antero-lateral lobe (*ascl*) from a posterior one (*pscl*). The other suture (*s*) extends almost longitudinally and marks off a third lateral invaginated scutal lobe (*marl*) situated alongside the lateral margin of the metatergum. This latter lobe exhibits the posterior notal process (*pnp*) to which the third axillary sclerite of the hind wing is connected. A muscle disc (*md*) is visible, posterior to this process (*pnp*).

The scutellum (*scl*) occupies the middle area of the tergum. Its median part is more or less depressed forming the median groove (*mg*) into which fits the thickened inner edges of the resting elytra. Other than this median part, the scutellum comprises two triangular scutellar areas on both sides of the median groove. These areas are convex and are uniformly but fairly sclerotized. They are separated from the scutal area by the scuto-scutellar suture (*vs*) which forms a large triangular internal ridge (*vsr*).

Both the scutum and the scutellum are bounded anteriorly by the transverse anterior suture (*ns*) which is also provided internally with two lateral ridges. Posteriorly, they are bounded by the posterior marginal suture (*s*) which represents the marginal internal ridge (*mr*). This marginal ridge differs from the preceding ridges by being a fairly sclerotized band-like structure. It is convex medially and supports the axillary cords of the hind wings.

The post-scutellum or post-notum (*pscl*) is a transverse sclerite lying posteriorly to the tergum, and bears two postero-lateral well developed post-phragma or phragmite (*pph*). It is more or less inclined internally and fairly sclerotized with a median posterior highly sclerotized portion.

The metapleura (Fig. 21) extend backwards till they reach the third abdominal segment. They are longer but less sclerotized than both the meso- and propleura. Each pleuron is divided into two sclerites, the episternum and the epimeron, by a diverging pleural suture (*pls*).

The episternum (*eps*) constitutes the major part of the metapleural area. Its anterior margin is slightly convex and forms with the externo-lateral margin a very sharp angle. Its lateral margins run parallel to each other. Posteriorly, its articulates with the hind coxa.

The epimeron (*epm*) constitutes a small postero-lateral region of the metapleuron. It is a small sclerite with an external wavy margin and a round posterior one, where it articulates with the third abdominal pleuron. From the antero-lateral region of the metapleuron two processes arise : (1) the basalare (*ba*), which is a semi-membranous process broader at base, tapering distally where it articulates with the head of the costal vein of the hind wing, and entirely attached to the episternum; (2) the pleural wing process (*wp*), which is a somewhat membranous triangular structure, located posterior and adjacent to the basalare and articularing distally with the first axillary sclerite and also with the head of the sub-costal vein of the hind wing.

Between the pleural wing process and the epimeron extends a semi-membranous area which gives off posteriorly a sclerotized metapleural hook (*h*) whose other end connects the metapleura with the meta-postscutellum.

The metasternum (Figs. 18 and 19) is about equal to the prosternum. It is convex and firmly connected to the mesosternum by a transverse suture (*s*) which extends in between the meso-coxae. Its anterior margin is laterally deeply curved downwards forming the posterior boundaries of the meso-coxal cavities, while its

posterior margin is laterally greatly curved upwards to form the anterior boundaries of the meta-coxal cavities. Its lateral margins are quite parallel. In the middle of its posterior region an incomplete, longitudinal suture runs inside a median groove and is ridged internally.

As no presternum is distinguished, the metasternum consists only of two sclerites, the basisternum and the sternellum, which are not easily defined from each other owing to the absence of any dividing suture.

The basisternum (*bs*) is sculptured and more or less convex.

The sternellum (*sl*) carries a postero-median sternellar piece, the furcasternum (Fig. 18, *fs*) which is deeply invaginated posteriorly. Into this invagination fits the inter-coxal process of the third abdominal sternum. To the internal edge of the furcasternum, articulates the endoskeletal furca. The furcasternum exhibits sideways two posterior projections (*ppr*) for the inner articulation of the hind coxae. The two metathoracic spiracles are smaller than the mesothoracic ones, and are located in the inter-segmental membrane connecting the meso- and metapleura.

Elytra

The keel-shaped elytra (Fig. 22) or the mesothoracic wings, when at rest, cover the posterior region of the mesotergum, the metatergum, and the whole abdominal terga, except the posterior region of the eighth tergum in the male, concealing underneath them the hind wings. Their straight anal margins meet together throughout their whole length in the mid-dorsal line forming the so-called dorsal suture. Alongside the costal margin of the elytron there is a band-like area narrowing gradually towards the distal end, and which represents the epipleuron (Fig. 22, *epl*).

When closed, the elytra articulate in the same fashion as illustrated by ALLUAUD (1902) "mortaise à gauche, tenon à droite". A narrow and fairly sclerotized band, which is clear at its apex, is located along each elytral anal margin (Figs. 22, and 23, *art*). The band of the left elytron forms a very shallow groove to receive the corresponding band of the right elytron.

Each elytron is strongly sclerotized and provided with longitudinal, straight, non-branching veins. Between the veins there are ten cells arranged in longitudinal furrows or striae, and eleven interspaces. The striae which are near the anal, costal and the apical margins are pigmented, oval and smaller than the rest of the striae which are nearly circular and less pigmented.

The eleven elytral interspaces (Fig. 23) represent : (1) the subcostal vein (*sc*); (2) the radius (*r*) lying next to the subcostal vein; (3) a secondary interradial vein (*ir*); (4) the radial sector (*rs*); (5) a secondary radio-medial vein (*mr*); (6) the media (*m*); (7) a secondary medio-cubital vein (*mcu*); (8) the cubtius (*cu*); (9) a cubito-anal vein (*cua*); (10) the first anal (A); (11) a second anal (*a*).

As to the striae they represent : (1) the post-subcostal (*psc*); (2) the ante-interradial (*air*); (3) the post-interradial (*pir*); (4) the post-radial (*pr*); (5) the ante-

medial (*am*); (6) the post-medial (*pm*); (7) the ante-cubital (*acu*); (8) the post-cubital (*pcu*); (9) the ante-anal (*an*); (10) the inter-anal (*sct*).

The axillary sclerites afford an efficient joint for the articulation of the wing with the thorax. There are three axillary sclerites associated with the mesotergal posterior wing process (Fig. 24, *pnp*):

(1) The scapular, or the first axillary sclerite (1, *ax*) which is an irregular plate connected to the posterior wing process of the mesotergum. It also articulates with the second axillary sclerites and the elytral basal plate.

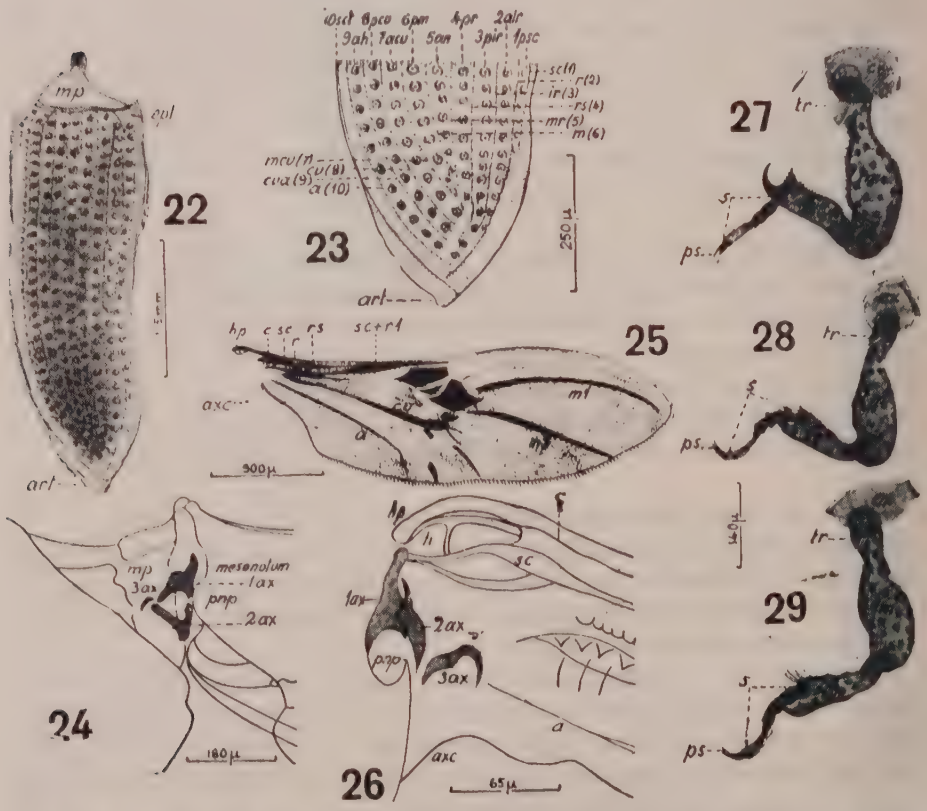

Fig. 22 : The left elytron, ventral aspect (*art*, sclerotized band; *epl*, epipleuron; *mp*, basal plate). — Fig. 23: The hind part of the elytron (*art*, sclerotized band; other lettering as in the text). — Fig. 24 : The axillary sclerites of the elytron (*1ax*, *2ax* and *3ax*, first, second and third axillary sclerites; *mp*, basal plate; *pnp*, mesonotal posterior wing process). — Fig. 25: The hind wing (*axc*, axillary cord; other lettering as in the text). — Fig. 26: The axillary region of the hind wing (*1ax*, *2ax* and *3ax*, first, second and third axillary sclerites; *axc*, axillary cord; *hp*, humeral plate; other lettering as in the text). — Figs. 27, 28 and 29 : The fore, middle and hind leg, respectively (*cx*, coxa; *fm*, femur; *ps*, pre-tarsus; *s*, tarsus; *tb*, tibia; *tr*, trochanter).

(2) The sub-scapular, or the second axillary sclerite (2, *ax*), which is v-shaped and connected with the first and the third axillary sclerites, and also with the elytral basal plate (*mp*).

(3) The flexor plate, or the third axillary sclerite (3, *ax*) being a small crescentic plate associated with the second axillary sclerite and also connected with the elytral basal plate (*mp*).

Wings

The wings (Fig. 25) are elongated but roughly triangular, with the apical angle more or less rounded. Their surface is provided with very fine hairs and the posterior margin is fringed with small setae.

Two regions are exhibited in the wing, the axillary region containing the axillary sclerites (Fig. 26) and the true "ala" or wing. This latter is composed of the "remigium" (Fig. 25), which occupies the antero-apical two-thirds of the wing surface, and the "vannus" which constitutes the anal region.

The wing veins are pushed to the basal region, while the apical area is devoid of such.

The costal vein (*c*) has a free basal portion whose proximal part is more sclerotized and represents the humeral pltae (*hp*). This latter articulates proximally with the meta-basalare (Fig. 21, *ba*).

The subcosta (*sc*) proximally has a free portion which articulates basally with both the first axillary and the metapleural wing process (Fig. 26). Distally, this vein fuses with the upper branch of the radius forming (*sc* + *r*1). On the proximal end of the subcosta, there are some fine setae directed downwards.

The radius (*r*) has a free basal portion. It branches into an upper anterior radius (*r*1) and a lower radial sector (*rs*). The (*r*1) is a highly chitinized vein. It is very thick at its distal half, where it fuses with (*sc*), as mentioned above. On the other hand, the (*rs*) is very short and ends distally free.

The cubitus (*cu*) begins freely and runs inclined downwardly till halfway of the wing where it thickens and then curves towards the anal margin of the wing. There are two fine setae on the thickened part of the cubitus where it bends.

The anal vein (*a*) also begins proximally free and proceeds with some inclination downwards till about one-third of the wing, and then bends towards the anal margin.

The wing articulates with the metathorax by the humeral plate, three axillary sclerites, and the axillary cord.

The humeral plate (Figs. 25 and 26, *hp*) lies anterior to the first axillary sclerite and articulates ventrally with the meta-basalare. It represents the base of the costal vein (*c*).

The first axillary sclerite (1*ax*) is roughly a triangular sclerite with an incised caudal margin. It articulates by its anterior head with the subcosta (*sc*) and ventrally with the metapleural wing process (Fig. 21, *wp*). Mesally, it articulates with the

anterior notal process (Fig. 20, *anp*), while it is partly embraced laterally by the second axillary sclerite (2, *ax*).

The second axillary sclerite (2, *ax*) is hinged to the outer margin of the first axillary.

The third axillary sclerite (3, *ax*) lies posteriorly in the axillary region, articulating proximally with both the caudal end of the second axillary sclerite (2, *ax*) anteriorly and the posterior wing process (*pnp*) caudally. Its lateral side is connected with the anal vein (A).

The axillary cord (*axc*) connects the wing to the caudal end of the meta scuto-scutellum.

Legs

Figures 27, 28 and 29 illustrate the pro-, middle and hind legs, respectively.

The fore coxa is more or less rectangular in shape. The middle coxa is nearly spherical and smaller than the fore coxa. The hind coxa is equal in size to the fore coxa and nearly oval. Each coxa has a socket for the articulation of the trochanter and the femur.

The trochanter (*tr*) is the smallest leg segment. It is triangular in shape with a round base and concaved sides. In each leg the trochanters are similar in shape, but the fore trochanter is the largest and the middle one the smallest.

The femur (*fm*) stands as the largest leg segment both in bulk and length, and has the same shape in the three legs. It is broader medially but slightly tapering distally, and greatly tapering proximally and then slightly broadening at its anterior inclined margins where it reaches the coxa lateral to the trochanter. Its distal end is rounded, forming a socket for the articulation of the tibia. The fore femur, which is comparatively broader medially than other femora, has short and stout spines on its inner side. The middle femur is the smallest and its inner margin is slightly bisinuate.

The tibia (*tb*) is shorter and more slender than the femur. Its distal extremity is curved, forming a very stout claw-shaped structure which is larger in the fore-leg than in the other two legs.

The inner side of the tibia bears fine hairs, especially at the distal portion. These hairs are dense in the fore tibia and very slight in the middle one. The fore tibia has also on its inner side few short and stout spurs.

The articulation of the tibia with the femur is of the socket-and-ball type.

Each of the fore, middle and hind tarsi (*s*) is apparently four-jointed; but actually each tarsus consists of five joints, the fourth and fifth joints being fused together. In each tarsus, the distal joint is the longest, and the fourth is the smallest. The distal joint carries the pre-tarsus. All the tarsal joints, except the fifth, carry hairs especially on their distal margin. The pretarsus (*ps*) is composed of two long,

stout, and slightly curved claws together with a ventral flexor plate, which is longer than broad and rounded proximally.

3. Abdomen

Both sexes have nine abdominal segments, seven of which are visible and the rest hidden.

When the elytra are removed, seven abdominal terga become visible in the female (Fig. 31) while in the male (Fig. 30) a small part of the eighth tergum can be seen protruding beyond the seventh.

The first abdominal tergum, in both sexes, is membranous and much reduced in area, but is distinguished by its pair of spiracles. The second tergum is entirely membranous, and is about as equal in size to the first one. The third tergum, which is larger than the first two terga together, is also membranous except a small region on both sides where there is some sclerotization. The fourth tergum, which is about the same size as the third, shows weak sclerotization in its lateral and posterior regions. Each of the fifth and sixth abdominal terga, is about the same in size as the fourth tergum. More sclerotization than on other segments can be seen on each one. The seventh tergum is longer, narrower, and much more sclerotized than the preceding terga. There is one pair of spiracles nearly equidistant and equal in size, in each tergum (2-7). The eighth tergum is also heavily sclerotized and sculptured, with a pair of setae coming out of each sculpture.

The female seventh and eighth abdominal terga differ in character from those of the male. The seventh tergum in the female is well developed and convex. It is shield-like, setiferous, with a rounded posterior margin. It covers completely the eighth abdominal tergum. This latter is smaller than the seventh and its posterior margin is rounded, finely corrugated, and armed with fine hairs. On the other hand, the seventh tergum in the male has the posterior margin almost straight, and it covers the major part of the eighth tergum leaving only a small uncovered portion of the eighth tergum protruding. Unlike the female, the eighth tergum in the male has the lateral margins inwardly folded.

In both sexes, there are seven sterna (Figs. 32, 33 and 34) of which the first and the second are rather small and obscured by the hind coxal cavities. Therefore, there are five visible sterna which are heavily sclerotized and sculptured. The third sternum is comparatively large, and has anteriorly a median elongation which overlaps the median posterior region of the metathorax. The fourth sternum is nearly equal in size to the third, while the fifth and the sixth are much narrower than the preceding one. The seventh sternum is semi-circular with its posterior and lateral margins rounded. Sternum eight shows great difference in either sexes. In the female (Fig. 38), it consists of an anterior long chitinous rod (*d*) which bifurcates posteriorly (*j*) and connects with the eighth tergum by a membrane. In the male (Fig. 36), it is divided into two small plates, the so-called genital plates, which are connected

together by a setiferous membrane. The ninth segment will be dealt with later, when describing the genitalia.

On either side of the abdomen, the pleura 3-6 (Fig. 34, *pl*) are visible and decrease in size gradually towards the posterior end. The third pleuron is prolonged anteriorly forming an articulate region which receives the hind end of the meta-epimeron (Fig. 34).

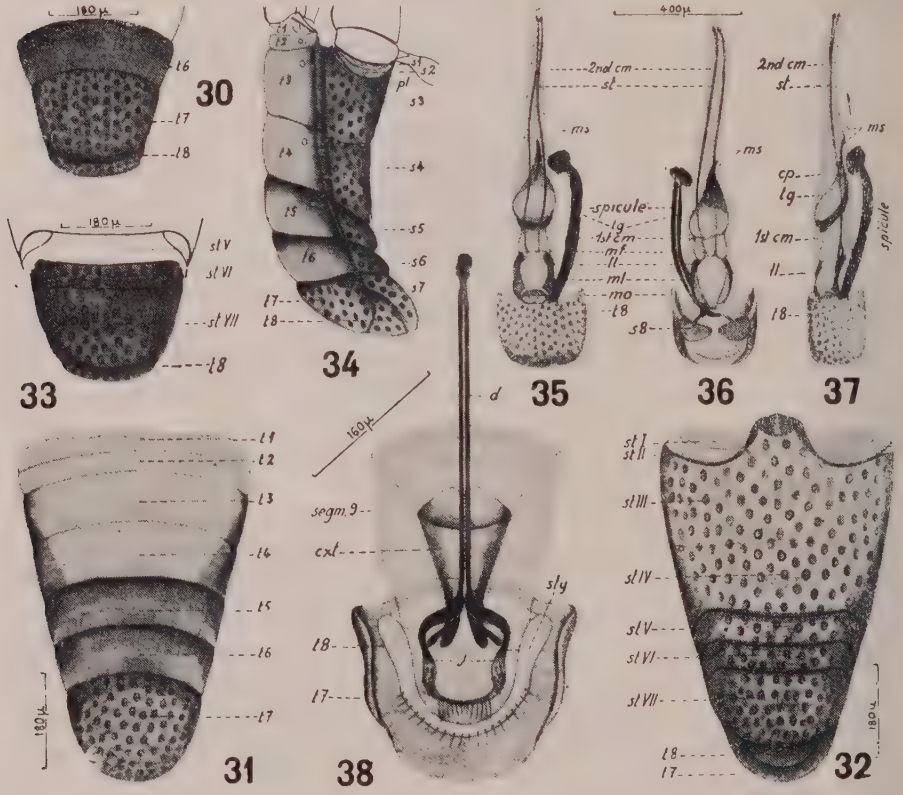

Fig. 30: The posterior terga of the abdomen of the male. — Fig. 31: The terga of the abdomen of the female. — Fig. 32: The sterna of the abdomen of the female. — Fig. 33: The posterior sterna of the male. — Fig. 34: The abdomen, lateral aspect (*pl*, pleura; *s*1-*s*7, sternum 1-7; *t*1-*t*8, tergum 1-8). — Figs. 35, 36 and 37: The male genitalia, dorsal, ventral and lateral aspect, respectively (*1st cm* and *2nd cm*, first and second connecting membranes; *cp*, cap-piece; *ll*, lateral lobe; *mf*, median foramen; *ml*, median lobe; *mo*, median orifice; *ms*, median strut; *s*8, sternum 8; *st*, strut; *t*8, tergum 8; *tg*, tegmen). — Fig. 38: The female genitalia (*cxt*, coxite; *d*, sclerotized rod; *sty*, styli).

4. Genitalia

In both sexes the genitalia are retractile and completely concealed within the body cavity when not in use.

In the male genitalia (Figs. 35, 36, and 37) the median lobe (*ml*) of the aedeagus is well developed and could be easily seen ventrally through the lateral lobes. It is a tubular jar-like structure with the median orifice (*mo*) located at its distal extremity and the median foramen (*mf*) at its basal end. The median lobe exhibits two very long anterior struts which reach to about the middle of the metatergum.

The lateral lobes surrounding the median lobes are completely fused together, forming a tubular structure. This latter is membranous ventrally (Fig. 36), strongly sclerotized dorsally (Fig. 35) and laterally (Fig. 37). So the median lobe can be best seen from the ventral aspect.

The tegmen (*tg*) is a sclerotized ring-piece surrounding the two long struts. It is connected to the lateral lobes by the first connecting membrane (1st *cm*), and has a ventral cap-piece (Fig. 37, *cp*) and a median strongly sclerotized strut (*ms*).

The aedeagus is ensheathed by a membrane, representing the second connecting membrane (2nd *cm*), connecting it with the eighth segment.

The spicule is a strongly sclerotized slender rod, extending ventrally up to about the fourth segment. It is attached to the second connecting membrane. Its distal end forms a flattened turban. This spicule is attached to the two genital plates of the eighth sternum by two arms (Fig. 36, *a*' and *a*").

The coxites (*cxt*) of the female genitalia (Fig. 38) are represented by two sclerotized lateral areas connected mid-ventrally and dorsally by a longitudinal membranous region forming a cone-like structure. Its ventral wall projects beyond the dorsal wall. The coxites are more sclerotized posteriorly than the anterior portion and they are connected with inter-segmental membrane (*t8-s8*) by a tubular semi-sclerotized structure. The styli (*sty*) are sclerotized palp-like structures which arise from the coxites and extend laterally and posteriorly.

IV. HISTOLOGY OF THE ALIMENTARY CANAL

1. Fore-gut

The pharynx (Fig. 40, *phy*) measures about 0.06 mm. in diameter. The intima (*in*), or the innermost layer, is thick and roughly thrown into six longitudinal folds of unequal heights. Outside the intima, there is an epithelial layer (*ephith*), in which the longitudinal folds are distinct. The cell boundaries are indistinct, and the nuclei, which stain deeply, are moderate in size and oval in shape. Covering the epithelial layer is a muscularis composed of a broad circular muscle layer.

The oesophagus (Fig. 41) is about 0.05 mm. in diameter. Its structure is similar to that of the pharynx, except that its folds are less deep.

The crop has the internal furrows continuous with those of the oesophageal epithelium, but shallower and more irregularly arranged. Internally, the crop is armed with slender, backwardly-directed spines (Fig. 43*s*) which almost always arise from the crests between the epithelial furrows. Although these spines appear

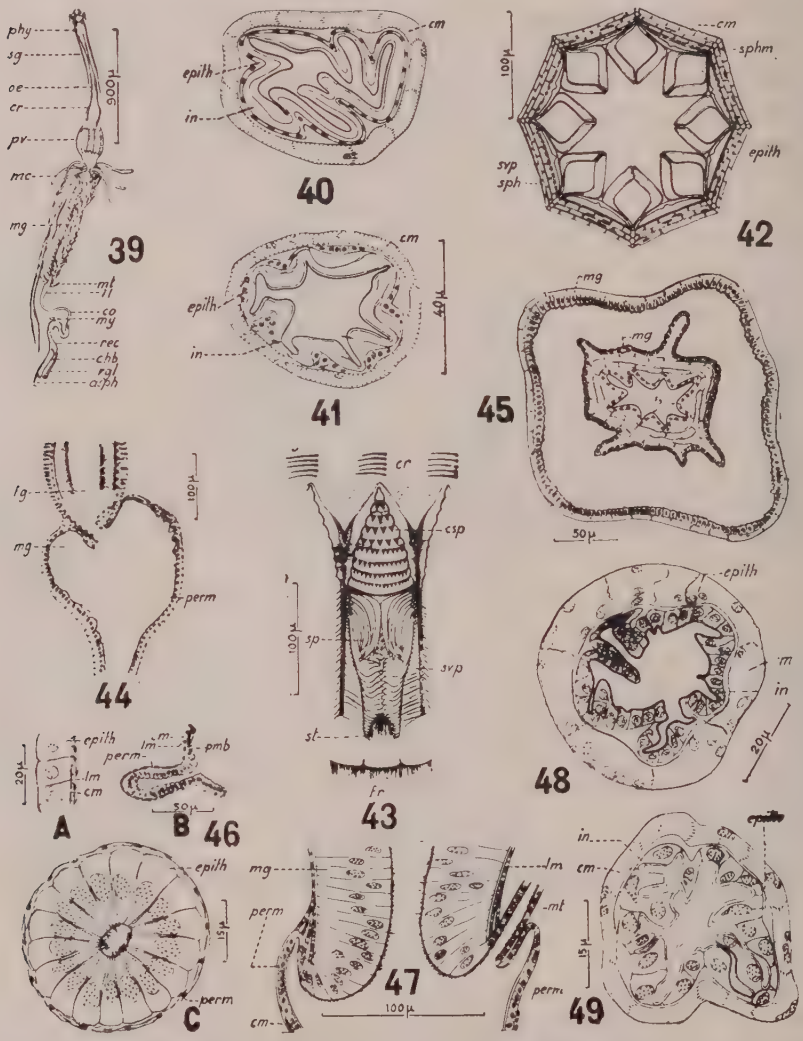

FIG. 39: The alimentary canal (*asph*, anal sphincter; *chb*, chitinous band; *co*, colon; *cr*, crop; *il*, ileum; *mc*, mesenteric caeca; *mg*, mid-gut; *mt*, malpighian tube; *my*, mycetome; *oe*, oesophagus; *phy*, pharynx; *pv*, proventriculus; *rec*, rectum; *rgl*, rectal gland; *sg*, salivary gland). — FIG. 40: Cross-section in the pharynx (*cm*, circular muscles; *epith*, epithelium; *in*, intima). —FIG. 41: Cross-section in the oesophagus (*cm*, circular muscles; *epith*, epithelium; *in*, intima). — FIG. 42: Cross-section in the gizzard (*cm*, circular muscles; *epith*, epithelium; *sph*, sphincter muscles). — FIG. 43: One of the eight pairs of series of plates constituting the proventriculus, seen from within after opening the proventriculus longitudinally (*cr*, crop; *csp*, cushion-like structure; *fr*, semicircular hair fringes; *s*, hairs of crop; *sp*, processes; *st*, setae; *svp*, plates). — FIGS. 44: Longitudinal section of the oesophageal valve (*fg*, fore-gut; *mg*, mid-gut; *perm*, peritrophic membrane). — FIG. 45: Cross-section in the oesophageal valve (*fg*, fore-gut; *mg*, mid-gut). — FIG. 46: A, longitu-

dinal section in some cells of the mid-gut; B, longitudinal section in the mesenteric caecum; C, cross-section in the mesenteric caecum (*cm*, circular muscles; *epith*, epithelium; *lm*, longitudinal muscles; *perm*, peritoneal membrane; *pmb*, peritrophic membrane). — Fig. 47 : Longitudinal section in the pyloric valve (*cm*, circular muscles; *lm*, longitudinal muscles; *mg*, mid-gut; *mt*, malpighian tube; *perm*, peritoneal membrane). — Fig. 48: Cross-section in the ileum (*cm*, circular muscles; *epith*, epithelium; *in*, intima). — Fig. 49: Cross- section in the colon (*cm*, circular muscles; *epith*, epithelium; *in*, intima).

to be uniformly distributed, the posterior ones are longer and more numerous than those laid anteriorly.

The proventriculus (Figs. 42 and 43) measures about 0.2 mm. in its widest part. Its size, however, varies with the degree of contraction of the powerful sphincter muscles (Fig. 42, *sph*) which surround it. These muscles bring into action the rows of backwardly-inclined, triangular, sclerotized plates which line the gizzard. These plates (Figs. 42, 43, *svp*) are certainly elaborations of the intima of this portion of the fore-gut, and are readily seen on opening the proventriculus mid-dorsally. They are set transversely to the axis of the fore-gut and are regularly disposed in eight double rows. Each double row contains about sixty pairs of plates (Fig. 43). Anteriorly, the plates bear close resemblance to a right-angled triangle, the vertical sides of the plates of one row being opposed to the corresponding sides of the plates of the accompanying row. The apices of the plates almost meet, therefore, in the centres of the double rows. In each row, the plates become shorter gradually towards the posterior end. These plates bear processes (Fig. 43, *sp*), the anterior-most of which are rather long and blade-like, while those situated posteriorly are more or less triangular in shape. Numerous fine setae (Fig. 43, *st*) arise from the extreme posterior plates of the double rows, thus closing the entrance gaps contained between every double row of plates. Anteriorly, the closure of such gaps is due to the fact that each double row of plates taking its origin anteriorly in a prominent cusnion-like swelling (Fig. 43, *csp*) at the level of the junction between the crop and proventriculus. There are, therefore, eight of these cushions which bear a characteristic armature, disposed uniformly around the entrance to the proventriculus. At the posterior end of the double rows of plates, there are two characteristic semi-circular hair fringes (Fig. 43, *fr*). Each fringe joins every double rows.

Behind the proventriculus, a typical oesophageal valve projects as a double annular fold into the mid-gut (Fig. 44). Internally, this valve is deeply furrowed, the furrows being actually the angles between the posterior continuations of the eight strongly curved walls of the proventriculus.

2. Mid-gut

The mid-gut is a long wide sac, extending from the level of the posterior end of the mesothorax to about the third abdominal segment. It is irregularly folded and held in place by tracheae. It begins at the base of the outer fold of the stomodaeal

invagination, where the stomodaeal intima ends. It measures about 0.1 mm. in diameter and carries along its whole length numerous intestinal caeca. At the anterior end of the mid-gut the caeca are exceptionally very long.

The inner striated borders of the columnar or cubical epithelial cells (Fig. 46, A and B) of the mid-gut are irregular and project into the lumen of the gut.

The food particles contained in the mid-gut lumen are surrounded by a pertitrophic membrane (*pmb*) which runs in close proximity to the striated border of the epithelium.

The musculature of the mid-gut is thin and composed of an internal sheath of circular muscle followed by an external longitudinal muscle layer, the fibers of which are numerous at either end of the mid-gut.

Just in front of the attachment of the Malpighian tubules and towards the posterior end of the mid-gut, the epithelial cells become longer and have their inner borders projecting far into the gut lumen, thus leaving only a narrow tract in the centre of the alimentary canal.

Each caecum (Fig. 46, B and C) has a central lumen leading to the mid-gut, and is lined by a single layer of columnar and cubical cells that have a striated border. A peritoneal membrane (*perm*) invests every caecum.

3. Hind-gut

The hind-gut extends from the posterior end of the mid-gut to the beginning of the anal sphincter, and is lined throughout its length with a sclerotized intima.

The ileum is about 0.5 mm. in diameter at its anterior part, but it narrows gradually towards the colon where the diameter becomes about 0.03 mm. The rectum is about 0.1 mm. in diameter, and there is a gland attached to the ventral and lateral sides at its posterior half. There is a band (Figs. 39 and 52, *chb*) which is continuous through the intima of the posterior rectum of both sides of its floor. This band ends its course through the rectal wall at the posterior end of the rectal gland where it becomes visible externally on the ventral surface of the posterior rectum. In the same way, the band projects externally at the anterior end of the posterior rectum but on the dorsal side.

The pyloric region is well developed and is represented by a ring of cubical epithelial cells at the anterior end of the ileum (Fig. 48), immediately behind the opening of the Malpighian tubules. This ring of cells encloses a wide chamber which is covered externally by a circular muscle layer continuous with that over the ileum.

In the ileum (Fig. 48), which is invested by a thick layer of circular muscle, the epithelium is folded inwards, the cells are exceedingly thin, and the intima is smooth.

The epithelium of the colon (Fig. 49) is also folded inwards and is composed of more or less flat cells. The colon has a layer of circular muscle which is thinner than that of the ileum.

The epithelial cells of the anterior rectum (Fig. 50) are folded inwards along six sides. The cells are large, and the intima is smooth. The muscles consist of an internal circular muscle layer and an external layer of longitudinal fibres.

A cross-section in the posterior rectum (Figs. 51 and 52) shows that the epithelial cells on the dorso-lateral sides are rather smaller than those of the anterior

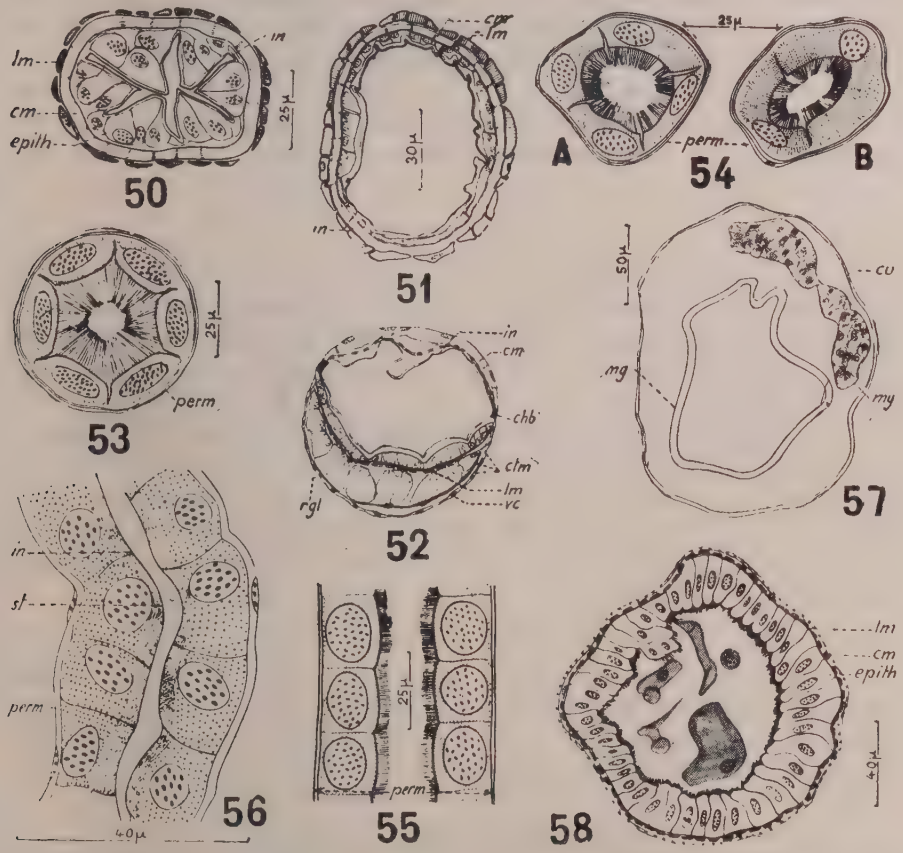

FIG. 50 : Cross-section in the rectum at the anterior part (*cm*, circular muscles; *epith*, epithelium; *in* intima; *lm*, longitudinal muscles). — FIG. 51: Cross-section in the rectum before the rectal glands immediately (*cm*, circular muscles; *in*, intima; *lm*, longitudinal muscles). — FIG. 52: Cross-section in the rectum with the rectal glands (*chb*, chitinous band; *cm*, circular muscles; *ctm*, connective tissue membrane; *in*, intima; *lm*, longitudinal muscles; *rgl*, rectal gland; *vc*, vacuoles). — FIG. 53 : Cross-section in the proximal part of the Malpighian tube (*perm*, periotoneal membrane). — FIG. 54: A, cross-section in the middle part of the Malpighian tube; B, cross-section in the free end of the Malpighian tube (*perm*, peritoneal membrane). — FIG. 55: Longitudinal section in the Malpighian tube (*perm*, peritoneal membrane). — FIG. 56: Longitudinal section in the maxillary glands (*in*, intima; *perm*, peritoneal membrane; *st*, striated border). — FIG. 57: Cross-section in the mycetome (*cu*, cuticle; *mg*, mid-gut; *my*, mycetome). — FIG. 58: Cross-section in the mid-gut, with protozoa (*cm*, circular muscles; *epith*, epithelium; *lm*, longitudinal muscles).

rectum. There is also a strong circular muscle band on the dorso-lateral side external to the epithelial cells. On the ventral and lateral sides of the posterior rectum, the epithelium is composed of cells, much larger in size than those on the dorso-lateral sides. Underneath these outer cells, there is a thin connective tissue membrane (Fig. 52, *ctm*) followed by the single layer of large cells of the rectal gland. The rectal gland is invested by a connective tissue sheath. Opposite the junction of the rectal gland (*rg*1) the lumen of the hind-gut is much dilated and forms a long wide chamber. Some pigmented rods surrounding a large central vacuole are also seen in some cells of the rectal gland.

The anal sphincter is lined internally with the cuticle and epidermis of the body wall, and is enveloped by strong circular muscle fibers.

4. Malpighian tubes

The Malpighian tubes (Fig. 39) are invested in a peritoneal coat which is richly supplied with tracheae. The cells enclosing the lumen of the tubes rest on a basement membrane and the cytoplasm of the cells shows the usual fine striation on the periphery. Internally, the cells carry the usual striated border which is composed of separate filaments.

A cross-section in the proximal part of the Malpighian tube (Fig. 53) shows that its lumen is fairly wide and is surrounded by about six cells. The filaments nearly meet in the centre of the lumen. The number of cells decreases towards the free end of the tube where the wall of the tube is made up of two cells only (Figs. 54 and 55). Also, the lumen narrows and the filaments of the striated border become much shorter.

5. Salivary glands

Each gland (Fig. 39) narrows gradually, but slightly, towards its external opening. The tube (Fig. 56) is invested in a peritoneal coat (*perm*) and is composed of epithelial cells that have numerous striations (*st*) near the lumen border. There is a fine intima (*in*) lining the whole tube.

6. The micro-organisms of the gut

Inside the mid-gut there are huge numbers of globular cocci, spore forming rod-shaped, and branched mycelia-like bacteria that are free-living in the lumen. The presence of these bacteria in enormous quantities suggests their significance to the digestion of the wood eaten by the insect.

A bilobed mycetome is found close to the anterior end of the rectum as shown in Figures 57 and 39. Each lobe is formed of a number of cells of variable size which stain deeply leaving always a clear zone around the nucleus. Both lobes are invested in a connective tissue membrane. The bilobed mycetome was smeared, fixed, stained, and then examined. There are no bacteria.

Large protozoan parasites, of the order Gregarinida (Fig. 58), are present intra-cellularly as well as extra-cellularly in the hind part of the mid-gut and the anterior part of the hind-gut.

V. SUMMARY

Adults *Rhyncolus cylindricus* Boh. were collected from a decayed poplar tree (*Populus* sp.) and from a willow (*Salix* sp.) found at Moharram Bey district, in the south-east region of Alexandria, Egypt.

A detailed study of the external morphology showed that :

1. — The head capsule is prolonged anterioly into a rostrum. It is well sclerotized and its sclerites are fused, the sutures being incomplete or vestigial. The gula is not represented.

2. — The mouth-parts are of the chewing type. All the usual parts are present except the labrum which is wanting. The sub-galea, galea, and lacinia are all represented by a simple lobe which is known as the mala.

3. — The antennae are of the geniculate type. In the female, they are slightly thinner and longer than that of the male.

4. — The prothorax is large, mobile, and deprived of pleuro-sternal sutures. The mesothorax is much reduced and is firmly connected to the metathorax.

5. — The elytra are horney and meet to form a straight mid-dorsal line. The wings belong to the cantharid type.

6. — No sexual dimorphism is distinguished in the legs. Tarsi apparently four-jointed.

7. — Both sexes have nine abdominal segments of which seven are visible and the rest hidden. The terga are rather membranous, while the sterna are more sclerotized and sculptured.

8. — The genitalia in both sexes are retractile and completely concealed within the body cavity.

The anatomy and histology of the alimentary canal is given in detail.

Large protozoan parasites of the order Gregarinida are present intra-cellularly as well as extra-cellularly in the hind part of the mid-gut. Inside the mid-gut there are huge numbers of globular cocci, spore-forming rod-shaped, and branched mycelia-like bacteria that are free living in the lumen.

VI. ACKNOWLEDGMENTS

This work has been done in the Entomology Department of the Faculty of Agriculture, Alexandrie University, under the supervision of Professor Dr. H. Zazou, head of the department, to whom the writer is greatly indebted for his guidance and encouragement. Deep gratitude is also wished to be expressed to Assistant

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PHOSPHAMIDON, A NEW PHOSPHOROUS COMPOUND AGAINST COTTON PESTS

(with 7 Tables)

by W. HAGNAUER, ING. AGR. (Basle), and A. SHOEB, B.SC. (Cairo).

INTRODUCTION

During the fall of 1955, CIBA Ltd., Basle (Switzerland), developed a new phosphorus compound under the name of Phosphamidon. It has the properties of a systemic insecticide; the active ingredient is taken up by the root, absorbed by the aerial parts of the plant, penetrates into the leaves and is translocated or carried in the sap to all parts of the plant. In the laboratory and greenhouse tests, this preparation showed a high insecticidal action against sucking as well as chewing insects and sucking instars of spider-mites. These first results called for experiments against insects affecting orchards, vines, vegetable and field crops.

As the cotton crop in Egypt is seriously attacked by some major insect pests which cause great annual losses, it was suggested to try this new systemic compound against some of these. The cotton worm, *Prodenia litura* F., a free living larva attacks the plants in big numbers, voraciously feeds on all green parts hindering the plants natural growth and seriously affects the annual yield.

The two bollworms *Platyedra gossypiella* Saunders and *Earias insulana* Boisd. live and feed most of their lives inside the cotton fruit (boll), soiling the lint, preventing its natural development and quality. These two insects are extremely difficult to combat with ordinary surface insecticides, while systemic insecticides promised to be more effective against them.

MATERIAL

The active ingredient "Phosphamidon" in the preparation CIBA 570 is Dimethyl-diethylamido-1-chloro-crotonyl (2)-phosphate.

Phosphamidon is completely water soluble, the preparation CIBA 570 used in these experiments contains 20% of it and is slightly blue in colour. Mamalian toxicity is relatively harmless and will be published elsewhere.

The purpose of this work is to get preliminary informations about the effect of field application of the Phosphamidon against some of the pests on cotton and to establish the optimum doses per acre necessary to control each pest, the duration of effectiveness, the spraying intervals, the influence of the population of predators before and after treatment, and the compound phytoxicity.

EXPERIMENTAL TECHNIC

The size of the experimental plot ranged from one quarter of an acre to an acre and a half with three to four replications. The first generation of *P. litura* on cotton appeared from the middle of June to the beginning of July 1956, somewhat late owing to an unusual cold spring. Bollworms appeared relatively late and the spider-mites and aphids were present from the middle of August, but without causing any severe damage to the crop. The population of predators was followed so far as it was possible in the relative small plots.

The control of efficacy was carried out as follows : in case of *P. litura*, by marking 20-40 egg masses followed by a daily inspection; for bollworms by opening 25-100 bolls from each plot at several intervals; in case of mites and aphids by collecting and counting insects on 25-50 leaves per plot, and for predators by controlling 25 flowers of 20 plants in each plot.

All the results obtained were controlled by an analysis of variance, in order to get an idea of the minimum significant difference of the experimental results.

For a comparative treatment the following quantities were chosen:

Test in Fouadya : 3 litres per acre of a commercially available emulsifiable product containing 60% of Octachlorocamphene; test in Behera : 4 litres per acre of the same product.

Most of the treatments were carried out as "low volume spray" with "Imperial" hand sprayers delivering 60-75 litres of spray per feddan under an initial

TABLE I

Percentage mortality of 1-4 days old larvae of Prodenia litura *on cotton sprayed with* C *570 by several methods*

Quantity CIBA 570 per feddan	Method of application	
	60 l. water per feddan 4 atm. pressure	400 l. water per feddan 30 atm. pressure
0,65 litre	42%	47%
1,30 litre	55%	85%
3,20 litres	95%	—
Min. sign. diff. 0,05	26%	

pressure of 3 kg./cm² decreasing to 1-$^1/_2$ kg./cm². The spraying bar was equipped by 6 nozzles Duikker No. 2. This system gives relatively big droplets with a limited penetration of the leaf masses. For this reason the spraying technic was compared with a high volume spray with fine droplets and high pressure. The results obtained are summarized in Table I for *Prodenia litura*. We found this fact entirely confirmed on later experiments against *Platyedra* and *Earias*. They point out a superiority of this spraying technic. Practical circumstances forced us to use the usual low volume spray.

RESULTS

Prodenia

The first generation of *Prodenia litura* presented an opportunity to test the necessary dosage of CIBA 570 for one feddan. In preliminary feeding experiments in petri dishes the results mentioned in Table II were obtained. There results indicated that the possible dosage lies between 1-2 litres per feddan.

TABLE II

Feeding experiment with CIBA *570 on* Prodenia litura, *larvae instar L. 1. High volume spray. Mortality percentage after 48 hours.*

Preparation	Spray concentration	Quantity per feddan	Mortality percentage
CIBA 570	0,1 %	0,5 litre	20
	0,2 %	1,0 litre	81
	0,4 %	2,0 litres	98
	0,8 %	4,0 litres	90
Standard	0,8 %	4,0 litres	95
Control	—	—	0
Min. sign. diff. P. 0,05			22

In view of this spraying technic, field experiments were carried out with 1,5 up to 4 litres CIBA 570 compared with 3-4 litres of the standard product. The results of the three main experiments observed 5-7 days after treatments are summarized in Table III.

From the continuous field observation on further generations followed, that persistence of insecticidal effect of CIBA 570 is relatively short. It was necessary to repeat the treatments every 10 days instead of 14 days compared with 3 litres of standard. With this method *Prodenia litura* could be very well controlled, and the quantity of 1,5 litre per feddan gave a good final result. No differences could be observed between 1,5 litre and 3,5 litres. Experiments to elongate the spraying

TABLE III

Mortality of newly hatched Prodenia *larvae from marked egg-masses in field experiments 5-7 days after treatment. Low volume spray.*

Preparation	Quantity per feddan	Experiment number		
		1	2	3
CIBA 570	0,75 litre	42%	32%	20%
	1,5 litre	55%	20%	60%
	3,5 litres	95%	80%	80%
Standard	3,0 litres	—	45%	60%
Min. sign. diff. P. 0,05		26%	30%	23%

intervals with higher doses failed and moreover the critical point of phytotoxity was reached a little above 3,5 litres CIBA 570 young cotton.

The action of CIBA 570 is relatively slow. The material does not give a knock-down effect. The time needed to kill the larvae is about 3-4 days as demonstrated in Table IV.

At Alexandria University, CIBA 570 gave good results when mixed with DDT.

TABLE IV

Reduction of the population of Prodenia litura *after spraying with* CIBA *570. Numbers of larvae caught by the sweeping method after the treatment of the 21st July.*

Preparation	Quantity	Dates of treatment	Numbers of larvae caught per plot	
			mean 22-24	mean 25-27
CIBA 570	1,5 litre	4/11/21	9,5	4,8
	3,0 litres	4/11/21	8,4	4,5
	3,5 litres	5/ /21	83,0	2,1
Min. sign. diff. P 0,05			2,6	

Platyedra gossypiella and *Earias insulana*

The Bollworms appeared late in our experimental field. In the experiment in the Behera the cotton was so high and dense in the middle of August that the spraying staff had difficulties to walk with the sprayers in the field. In view of the density of the plants the quantities of insecticides were increased to 3,5 and 4 litres in experiment number 2, whilst in number 1 the treatment had to be stopped altogether. The results obtained are reported in Table V.

TABLE V

Control of Bollworms with CIBA *570. Percentages of attacked bolls.*

Preparation	Quantity per feddan	Experiment number 2		Experiment number 3	
		7.8	17.8	12.9	21.9
CIBA 570	1,5 litre			5	16
	3,0 litres			6	17
	3,5 litres	7	20	14	10
	4,0 litres	9	9	3	10
Standard	4,0 litres	9	11		
Control	—		35	66	66
Min. sign. diff. P 0,05		6%		10%	

These dates indicated that the dosage of CIBA 570 against Bollworms must be increased corresponding to the size of the plants on 3-3,5 litres. Results of the experiment of Ministry of Agriculture record good effect against bollworms.

Red spiders and Aphids

The infestation of the fields from *Tetranychus telarius* and *Aphis gossypii* was moderate in 1956. Only one count was carried out, delivering the data reported in Table VI. All the tested concentrations were quite effective against these two pests. At Sakha it was noticed that treatment with CIBA 570 was not followed by mites attack.

TABLE VI

Infestation of leaves by Tetranychus telarius *and* Aphis gossypii.

Preparation	Quantity per feddan	Percentage of leaves attacked by	
		T. telarius	*A. gossypii*
CIBA 570	1,5 litre	0	0
	3,0 litres	0	0
	3,5 litres	0	0
Standard	3,0 litres	37,5	3
Control	—	38,5	15

Predators

Predator population in cotton fields is affected by most of the usual contact insecticides. In order to obtain data on this influence, the population of predators was controlled several times. Clear and significant differences were found after the fourth treatment (Table VII). Later in the season the population decreased in a general way, probably due to an absence of Aphids and Red spiders in the field.

TABLE VII

Total of predators on 20 controlled plants before and after the fourth treatment, with CIBA *570 and standard.*

Preparation		Number of predators		Population percentage
		before treatment	after treatment	
CIBA 570	3,0 litres	30	30	100
	3,5 litres	22	17	57
	4,0 litres	17	14	47
Standard	4,0 litres	9	7	23
Min. sign. diff. 0,05		7		—

The reported dates indicate that the highest dosages used have a marked slighter effect on predators than a pure contact insecticide.

SUMMARY

CIBA 570 containing 20% of Phosphamidon is a phosphorous systemic insecticide developed by CIBA Ltd., Basle 1955. It was found effective against sucking and chewing insects in laboratory and greenhouses. First field trials in Egypt 1956, gave promising results against *P. litura* F., *P. gossypiella* Saunders, and *E. insulana* Boisd. It showed good results against aphids and spider mites. Optimum dosage per acre for *P. litura* may be 1.5 litre, for bollworms 3 litres. Persistence of insecticidal effect is 7-10 days. Intervals of treatments must not exceed 10 days. It is not followed by red mites attack as in the case of some other insecticides. Due to its selective systemic action, predators are not so highly affected as by contact insecticides. The critical point for phytotoxicity is reached a little above 3.5 litres on young leaves. CIBA 570 is relatively harmless for the spraying personnel.

Further studies and experimentation are recommended.

ACKNOWLEDGMENTS

This work has been carried out under the supervision of Prof. Dr. HAMID SELIM SOLIMAN, former Professor of Entomology and sub-Rector of the Cairo University, without whose help and suggestions this study could not have been completed. We feel very much indebted to him and hereby record our thanks. Our thanks are also due to the authorities and staff of the Agricultural Colleges of Alexandria, Ein-Shams Universities, and to the BLESS Family for allowing experiments to be carried out at their farms.

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THE SPINY BOLLWORM, *EARIAS INSULANA* BOISD., INFESTING MAIZE EARS IN EGYPT

[*Lepidoptera* : *Agrotidae-Acontiinae*]

(with 5 Text-Figures)

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INTRODUCTION

Earias insulana Boisd. is a well known pest of cotton in Egypt. Other known host plants are bamia or okra (*Hibiscus esculentus*), til or deccan hemp (*Hibiscus cannabinus* and other related species), devil's til (*Hibiscus trionum*, a weed), ornamental hibiscus (*Hibiscus rosa-sinensis*), *Hibiscus mutabilis*, hollyhock (*Althaea rosea*), khobbeza (*Malva parviflora*), *Malva sylvestris* (a weed), and the abutilons in gardens. According to Mr. MOHAMED SOLIMAN EL-ZOHEIRY (unpublished notes), it also feeds on karkadeih (*Hibiscus sabdariffa*) in Kom-Ombo.

The only record of this pest feeding on maize in Egypt is that of WILLCOCKS (1925). According to this author, "a larva of this cotton bollworm has once been found feeding in a maize cob. Possibly it is not quite so rare in maize as we think since in parts of the Belgian Congo, *Earias* spp. are said to oviposit more freely on maize than they do on cotton plants growing along side of it". This same record was mentioned again by WILLCOCKS and BAHGAT (1937), who added "in Egypt, so far as we know, maize-feeding habit is exceedingly rare".

In September 1955, the present authors noticed the presence of *Earias insulana* larvae in samples of ears of sweet and field maize collected from the farm of the Faculty of Agriculture, at Giza. Regular observations carried from September 1955 to December 1956 indicated that their presence in maize ears in Egypt is by no means rare (in Giza at least). Only the unripe ears are attacked.

The present report is meant to call the attention to the fact that *Earias insulana* may be considered a pest of maize ears in Egypt. It gives an account of the time of its appearance on maize, the type of injury, and feeding habits.

TIME OF APPEARANCE

The infestation of maize ears is quite apparent in the "nili" crop during September and the first half of October, then it decreases and becomes sparse in December. The begining of this period coincides with the harvesting of cotton. It is likely that the moths resulting from larvae reared in cotton bolls become attracted to the silking maize plants. Ears collected during late May, June, and July, from a crop grown in March, 1956, were free from infestation.

TYPE OF INJURY AND FEEDING HABITS

Usually, the injury starts at the top of the ear (Fig. 1) The larvae eat in the silk, which looks as if it were cut off by a blade. Accumulations of moist pasty frass are to be seen. The developing kernels, specially the upper ones, are attacked. It is not uncommon that kernels in the middle or the bottom of the ear are also attacked (Fig. 2). The larvae may also feed on the surface of the fleshy core of the developing ear.

In one case only, a young larva was found on the dry staminate inflorescence (tassel). No features of feeding were noticed, and it is likely that this larva was just wandering about. In another case, a larva was found tunnelling in the rachis of the tassel (Fig. 3).

The way how the larva attacks the kernels was observed in the laboratory. The larva has a predilection for meandering about before selecting the site of feeding. At a space between two kernels in one row, the larva begins to gnaw into one kernel near its point of attachment to the core (Fig. 4). It feeds on the soft contents of the kernel until the latter becomes an empty husk. While the kernel becomes gradually emptied of its contents, the larva pushes itself into it. If the larva is small in size, it may become entirely enclosed into the husk. These husks are easily spotted as they look darker in colour than the sound kernels. After emptying one kernel, the larva may attack adjacent kernels while still enclosed in the husk. It is not uncommon to find a full grown larva stretched inside two adjacent husks. While feeding the larva expels pellets of excrement, often in a chain-like formation. These pellets accumulate near the attacked kernels.

Although in the present work no eggs could be observed, it is assumed that the eggs are laid on the silk, as in the case of the corn earworm *Chloridea obsoleta* F. Young larvae were found among the silk, and in many cases, although no holes

were seen in the ears husks, larvae of different sizes were found inside the ears. The presence of larvae in sites other than the silk and top of the ear is attributed to their crawling downwards.

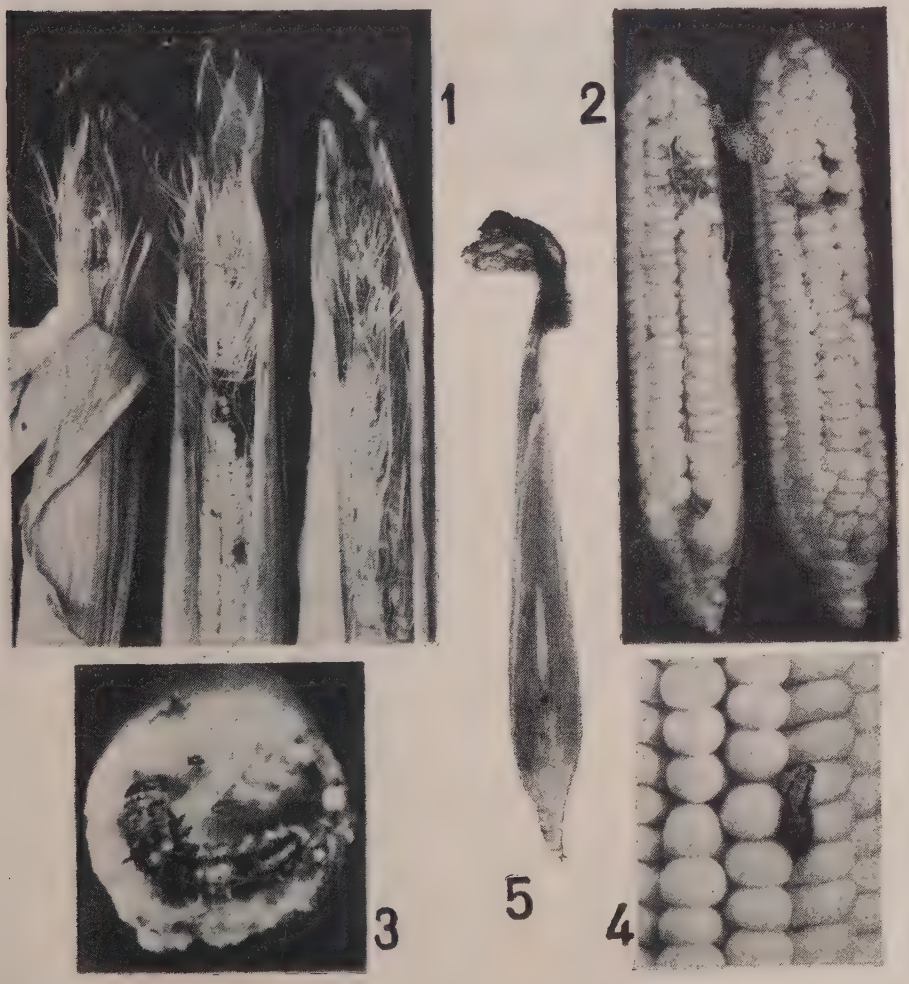

FIG. 1: Larvae feeding in silk and upper parts of the ears. — FIG. 2: Larvae feeding on kernels. — FIG. 3: Larva tunnelling in the rachis of a tassel (upper part of rachis cut off). — FIG. 4: Larva attacking a kernel. — FIG. 5: Maize ear showing cocoon at top and exit hole at bottom.

Pupation takes place outside the ear. In most cases the full grown larva leaves the ear through the top to pupate outside. In one case, however, a cocoon was found

near the top of an ear's husk and a hole at the lower part of the same husk (Fig. 5). When the husk was removed, damaged kernels showed symptoms of injury typical to this insect. It is likely that the pupating larva came out through this hole.

Usually, one or two larvae are found in a single ear, but up to four larvae may be found. These larvae are commonly of different sizes. Cocoons were found attached to the dry silk, the leaves blades and the ears husks.

In the laboratory, moths were reared successfully from larvae fed on maize ears.

ACKNOWLEDGMENT

The authors are indebted to prof. Dr. Ahmed Salem Hassan, head of the Department of Plant Protection, Faculty of Agriculture, Cairo University, for his interest in the subject and for reading the manuscript.

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ON THE SUSCEPTIBILITY OF THE EGYPTIAN HOUSE-FLY, *MUSCA DOMESTICA VICINA* MACQ., TO SEVERAL INSECTICIDES

[*Diptera*]

(with 6 Text-Figures and 2 tables)

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Among the considerable mass of knowledge that has accumulated in recent years on house fly toxicology, comparatively little work has been done on the levant house fly *Musca domestica vicina*. Perhaps the only important insecticidal work on this species in Egypt is that of GAHAN and WEIR during the years 1950-53. These authors, in an attempt to control house-flies in Egyptian villages, conducted numerous experiments and field observations to test the residual effect of some chlorinated hydrocarbon insecticides.

In the present paper, a preliminary study of the susceptibility of male and female *vicina* to DDT, lindane, methoxychlor, dieldrin, pybuthrin (2/16 pyrethrins Piperonyl-butoxide) and parathion was carried out in the laboratory and the results were compared with those on *Musca domestica*. The author wishes to thank M.A. Attia, demonstrator in the Entomology Department, for his valuable assistance in the conduction of these experiments.

MATERIAL AND METHOD

A constant stock of flies reared on milk (HAFEZ, 1948) was maintained in the laboratory. Standardized quantities of the insecticide in acetone were applied topically to the mesonotum of the fly using a very small wire loop which, when dipped in the solution, holds a droplet of a constant volume. The latter was determined by

making a concentrated solution of the insecticide (e.g. DDT) in a known volume of acetone. By successive dipping of the wire loop in the solution and rapid releasing of the droplets on a clean glass rider held by the hook of a sensitive torsion balance (0.1 mlg.), the weight of the insecticide liberated from a certain number of these highly evaporating acetone droplets was recorded from the balance and the volume of a single droplet was then calculated. For instance, by using a 10% DDT solution in acetone, the volume of one droplet from which 0.087 mlg. of DDT was liberated would be:

$$\frac{0.087 \times 100}{10 \times 1000} = 0.00087 \text{ cc.}$$

From the concentration of the insecticide used and the volume of the droplet, the quantity of the insecticide deposited by the loop was determined for each experiment.

The toxicants were applied in various concentrations as weight (or volume) per volume. The flies were anaesthetised by Co_2 within a period of 15 minutes during which no mortality occurred.

The flies used were 2-3 days old and fed on sugar and water. Both sexes were tested separately. Twenty flies of each sex were treated with each concentration of a given insecticide. Cylindrical pint milk cartons capped with wire screens were used for holding the flies after treatment. Each carton was supplied with a moistened piece of cotton wool and a sugar cube which served as food during the holding period. The experiments were conducted under room conditions (26-29°C.; 50-60% R.H.) and the counts were made 24 hours later.

Dosage in micrograms (or cubic microns in case of liquids) per fly were plotted against percentage mortality on log-probit paper. The straight line curve was drawn by inspection and the LD_{50} (the quantity of toxicant required to kill 50% of the flies treated in 24 hours) value of each compound was determined from the curve. The tests were replicated when necessary.

RESULTS

The results of tests conducted with six insecticides are shown in Table I and Figures 1-6. In all cases, the female Egyptian house-fly, *Musca domestica vicina*, was normally less susceptible than the male to the effects of all the insecticides tested.

This seems to be in general agreement with the results obtained in the house-fly *Musca domestica* (Barber and Schmitt, 1948; Bruce and Decker, 1950; Busvine, 1951) and the lesser house-fly *Fannia canicularis* (Lewallen, 1954).

The high degree of tolerance of the Egyptian house-fly to DDT and great susceptibility to Lindane and dieldrin were most striking. Methoxychlor ordered next tolindane and dieldrin yet its toxic effect was much inferior. Pybuthrin gave

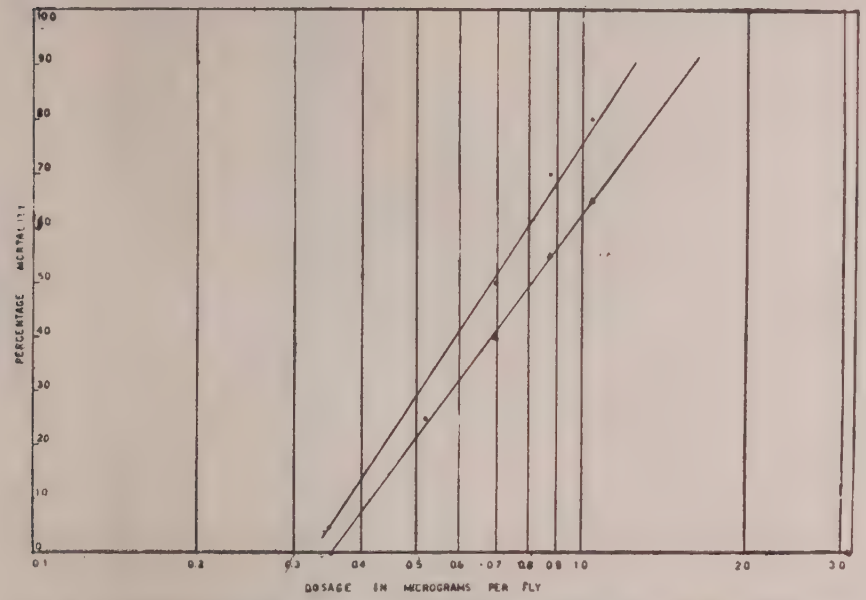

FIG. 1: The toxicity of DDT applied topically to male and female *Musca domestica vicina* (circles = males; triangles = females).

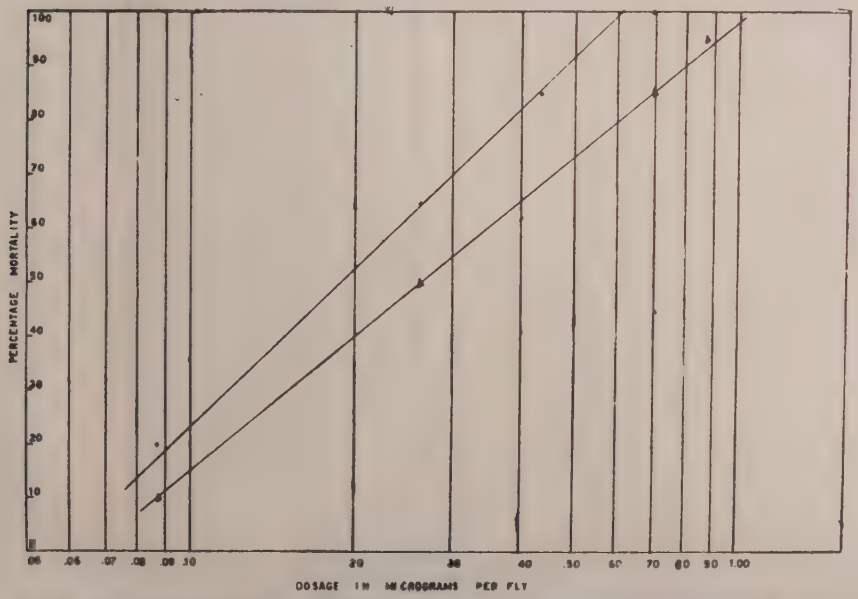

FIG. 2: The toxicity of Methoxychlor applied topically to male and female *Musca domestica vicina* (circles = males; triangles = females).

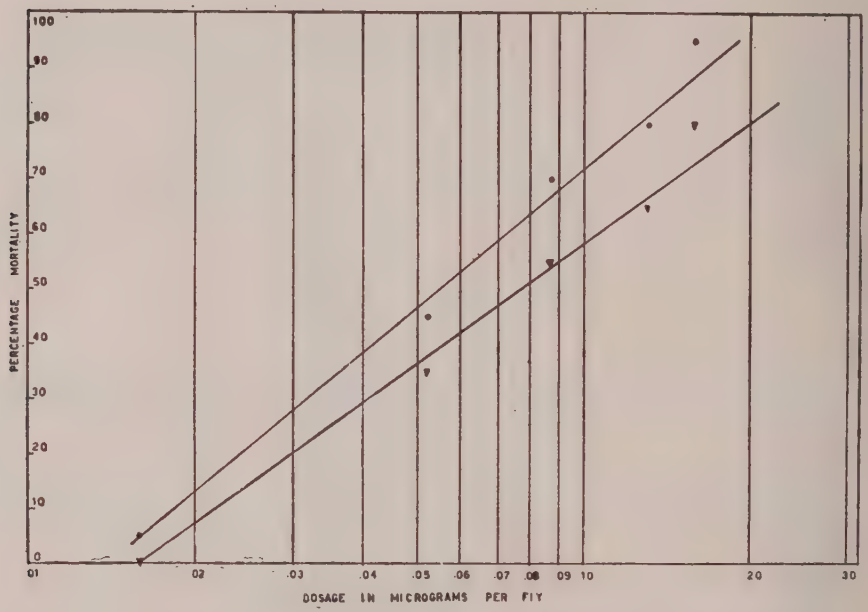

FIG. 3: The toxicity of Lindane applied topically to male and female *Musca domestica vicina* (circles = males; triangles = females).

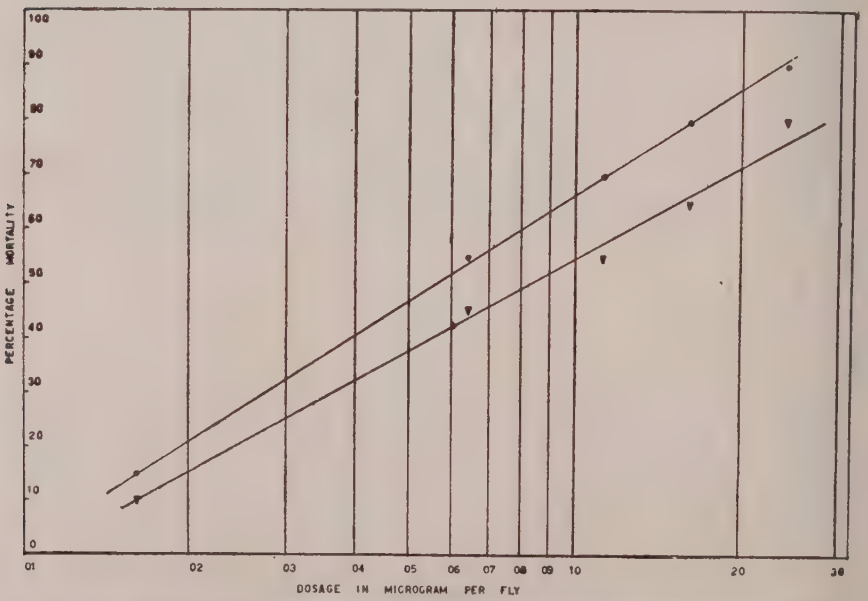

FIG. 4: The toxicity of Dieldrin applied topically to male and female *Musca domestica vicina* (circles = males; triangles = females).

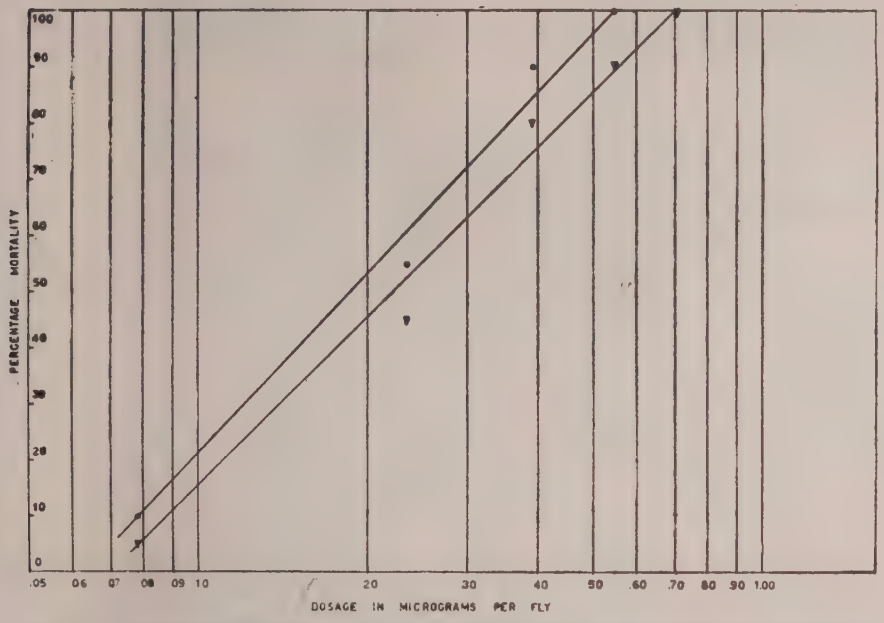

FIG. 5: The toxicity of Pybuthrin applied topically to male and female *Musca domestica vicina* (circles = males; triangles = females).

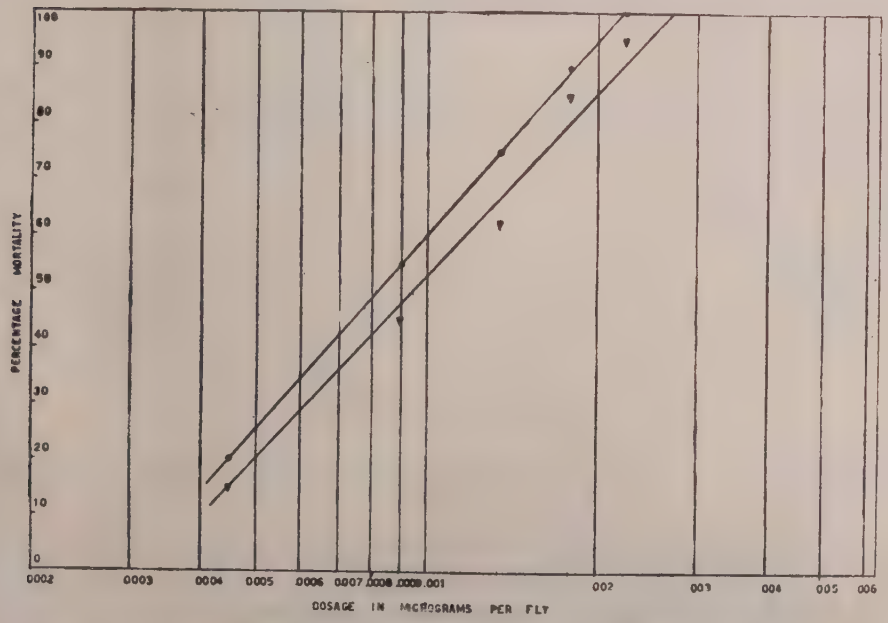

FIG. 6 : The toxicity of Parathion applied topically to male and female *Musca domestica vicina* (circles = males; triangles = females).

about the same toxic effect as methoxychlor. The organo-phosphorous compound parathion was the most powerful toxicant to which the flies showed greatest susceptibility.

TABLE I

A comparison of the LD_{50}'s in micrograms of U³ per fly (applied topically) for the male and female Musca domestica vicina

Compound	Male	Female
DDT	0.692	0.815
Methoxychlor	0.188	0.264
Lindane	0.0550	0.0766
Dieldrin	0.0556	0.0827
Pybuthrin	0.1863 (1.035.000 U³)	0.2214 (1.230.000 U³)
Parthion	0.0008 (3.180 U³)	0.0009 (3.670 U³)

A comparison of the LD_{50} values for the female *Musca domestica vicina* with those of the susceptible female *Musca domestica* (LEWALLEN, 1954), on the basis of micrograms of insecticides per fly (Table II) showed that the Egyptian house-fly was about 25 times more tolerant to DDT, 4 times to methoxychlor, 7.5 times to Lindane and 2.5 times to dieldrin.

TABLE II

A comparison of the LD_{50} values (in micrograms of insecticide per fly) for the female Musca domestica *and female* Musca domestica vicina

Compound	*domestica*	*domestica vicina*
DDT	0.033	0.815
Methoxychlor	0.068	0.264
Lindane	0.010	0.0766
Dieldrin	0.031	0.0827

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STUDIES ON THE ECOLOGY OF *MUSCA SORBENS* WIED. IN EGYPT

[*Diptera*: *Muscidae*]

(with 5 Text-Figures and 17 Tables)

by MAHMOUD HAFEZ, M.SC., PH.D., F.R.E.S.,
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I. Introduction. — II. Nomenclature. — III. Geographical distribution. — IV. Historical review. — V. Material and methods. — VI. Habits of the adult. — VII. Emergence. — VIII. Mating and oviposition. — IX. Breeding media. — X. Seasonal prevalence. — XI. Longevity. — XII. Flight range. — XIII. Sex ratio. — XIV. Colour preference. — XV. Summary. — XVI. Bibliography.

I. INTRODUCTION

The fact that flies are a great nuisance to man, pales into insignificance if compared to their potentialities as vectors of disease. In Egypt, flies are common and inflict heavy losses every year upon the human population particularly among children because of their activities in the transmission of enteric infections and other diseases.

One of these flies, *Musca sorbens*, relatively little known as compared with the common house fly *Musca domestica vicina*, has gained increasing importance recently and more attention has been focussed on its relation to public health as a possible active transmitter of eye diseases in Egypt.

In view of the fact that our present knowledge about this important fly in Egypt is extremely inadequate, it was deemed necessary to carry out rather detailed investigations on its ecology, biology and behaviour including its relation to eye diseases in Egypt. The results of our ecological studies on the adult fly are included in the present paper which is the first in a following series on this species.

II. NOMENCLATURE AND ORIGINAL DESCRIPTION

Musca sorbens Wied. belongs to the family Muscidae of the Order Diptera-Cyclorrhapha. The genus *Musca* includes 68 possibly valid species (WEST, 1951). There are two sub-species of *sorbens* : *sorbens sorbens* Wied. and *sorbens alba* Mall.

The following are synonyms of *Musca sorbens* Wied. which were used by previous authors : *humilis* Wied., *spectanda* Wied., *latifrons* Wied., *angustifrons* Thoms., *mediana* Wied., *sordidissima* Walk., *bivittata* Thoms., *eutaeniata* Big. (*enteniata* Big., HEWITT 1914), *biseta* Hough., *vetustissima* Walk., *pumila* Macq., *corvina* Frogg. (nec. Fabr.), *promiscua* Awati, *minor* Patton (nec. Macq.), *dichotoma* Bezzi, *niveisquama* Thoms., *specularis* Rond.

M. sorbens Wied. is a biologically distinct species, and like *M. domestica vicina* Macquart has a more tropical distribution. However, *sorbens* differs from *vicina* in having two broad thoracic stripes. These are four in the latter species. The following is WIEDEMANN'S original description translated in English (1830) :

"58 *M. sorbens.* Greyish; thorax with white fasciae; abdomen blackish; yellowish-tessellate. Greyish with white thoracic stripes and blackish, yellowish-tessellate abdomen. Length 2.5 lin. female, from Sierra-Leone.

Antennae black; lower face and cheeks black, with silky-white sheen. Frons deep black, with somewhat yellowish-white silky shining margins of eye cavities. Thorax greyish, almost submetallic shining, with three white-shining stripes, the exterior (stripes) very broad, the median somewhat less broad, and in other direction appearing very distinctly grey, on somewhat paler ground. Sides of thorax with white sheen, which forms nearly 2 oblique fasciae. Abdomen blackish, with large yellowish-silky shining tessellation. Wings colourless. Veins yellow at the base; halteres and squama yellowish-white. Legs black".

More recently, PATTON (1926) gave a short account of the distinctive characters of this species, and the morphological differences between the two sexes, which differ from each other in the following : (1) the relative width between the eyes; 2) the thoracic stripes; (3) the colour pattern of the abdomen; (4) the genitalia.

These differences are tabulated as follows :

Structure	Male	Female
Vertex	narrow	broad
Thoracic stripes	broad and continuous	narrow and bifurcated
First abdominal tergite	entirely dark brown	entirely black
Last abdominal tergite	without admedian stripes	with admedian stripes
Ventral side of abdomen	yellowish	greyish
Genitalia	minute tubercles	large sclerites

III. GEOGRAPHICAL DISTRIBUTION

M. sorbens, a house-frequenting fly, is widespread in the Ethiopean, the Oriental and probably in the Australian regions (WEST, 1951). Also, this species is frequently recorded in the Palearctic life zone.

It was first described by WIEDEMANN (1830) from Sierra Leone; but later it was recorded by different authors from the following localities :

AFRICA : Khartoum (BALFOUR, in HEWITT, 1908), Rhodesia (BEVAN, 1926), Nyasaland (LAMBORN, 1934; AUSTIN and MAYNE, 1935), Uganda (Annual Report of the Medical Department, 1940), Morocco (GAUD et al., 1954).

ASIA : Aden (HEWITT, 1914), Mesopotamia (PATTON, 1919), Philippine (PATTON, 1923; DE LA PAZ, 1938; OMAN and CHRISTENSON, 1947), North China (MENG and WIENFIELD, 1938), India (AWATI, 1920; ROY and SIDDONS, 1940; DEORAS and JANDU, 1943), Azerbaijan (TROFIMOV, 1942), Tadjikistan (VAINSHTEIN and RODOVA, 1940; SMIRNOV, 1940; ZIMIN, 1946), Jordan (WEST, 1953).

EUROPE : Italy (FRANCHINI, 1927), Sicily (SACCA, 1952).

OCEANIA : Australia (HILL, 1921), Guam (HARRIS and DOWN, 1946; HALL and BOHART, 1948; BOHART and GRESSIT, 1951).

In Egypt, this species was first recorded by HEWITT (1914) from Suez, and by PATTON (1926) who stated that : "It is common in the mediterranean area along the North Africal coast, and boards all steamers going East through the Suez Canal". HAFEZ (1941) collected it from the vicinity of Cairo and the country; he further stated that it was frequently met with on the edge of the desert. More recently other investigators, e.g. SABROSKY (1952), PEFFLY (1953) and DECOURSEY et al. (1956) recorded it from different localities in lower Egypt. The former author, however, added that it was the predominant fly in Feiran oasis in central Sinai.

The present authors collected *M. sorbens* from several localities of the Egyptian territory, including both the desert and the Nile valley. It is common and widespread and ranks next in abundance to our common house fly *M. domestica vicina*. The Egyptian localities from which the fly was collected are :

NILE VALLEY : Abou Atata, Aghour El-Kubra, Aghour El-Sughra, Ashtar, Aswan, Banha, Barada, Cairo, Fayoum, Giza, Harb, Kuniisa, Luxor, Nazla, Quaranfil, Sindibis, Talbia, Tanta, Tersa and Zagazig.

ARID AND SEMI-ARID ZONES: Abou Roash, Cairo-Alexandria desert road, Cairo-Suez desert road, Helwan, Karoun, Suez, Wadi - Digla, and Wadi Hof.

IV. HISTORICAL REVIEW

The review of literature reveals that no detailed account of the biology of *M. sorbens* seems to have been previously given. Many workers, however, gave short notes on such aspects of biology as the breeding media of the fly, its habits, seasonal abundance, etc. Several substances which served as breeding grounds for

sorbens were reported by workers from different parts of the world. For instance, the fly was bred from human excrement by AWATI (1920) and ROY and SIDDONS (1940) in India, PATTON (1920) in Mesopotamia, AUSTIN and MAYNE (1935) in Nyasaland, SMIRNOV (1940) in Tadjikistan (Russia), HAFEZ (1941), SABROSKY (1952) and PEFFLY (1953) in Egypt, HARRIS and DOWN (1946) in Guam, and GAUD et ál. (1954) in Morocco, North Africa.

Animal dung served also as a breeding substance. MENG and WIENFIELD (1938) in China, VAINSHTEIN and RODOVA (1940) in Russia, and SMIRNOV (1940) in the same country, bred the fly from pig dung. PATTON (1920) in Mesopotamia, JACK (1931) in Rhodesia, HAFEZ (1941) and PEFFLY (1953) obtained the fly from cow dung.

Other substances, such as decomposing carcasses and garbage, were reported as rearing media by BEVAN (1926) in Rhodesia, and DE LA PAZ (1938) in the Philippines, respectively.

Scattered observations on the habits of the fly and its relative abundance were made by some authors. MENG and WIENFIELD (1938) working in China, and DE LA PAZ (1939) working in Philippine, have pointed out that the fly usually occurs in great numbers ranking next to *M. domestica vicina* among flies frequenting houses. The former authors have also carried out some indoor and outdoor experiments and noticed that the average density in the indoor stations were about twice as great as in the outdoor ones. They further added that the fly manifests itself in greatest abundance in August after which a gradual fall takes place until it disappears in December. Nearly similar observations on seasonal prevalence were reported by ZIMIN (1946) working in Russia who stated that *M. sorbens* appeared at the end of June and became abundant in August and the first half of September. This author has further studied the temperature and humidity ranges (24-27 °C. and 32-35% R.H.) at which the fly entered houses. In India, DEORAS and JANDU (1943) emphasized the importance of the fly and advocated certain measures for its control; these authors pointed out that the fly was frequently met with in houses. In other countries, on the other hand, the fly hardly enters houses and is usually abundant in the open on vegetation, markets, open air restaurants, etc. This almost outdoor nature of the fly was reported by SMIRNOV (1940) in Russia, and GAUD et al. (1954) in Morocco, North Africa. SABROSKY (1952), working in Egypt, stated that *M. sorbens* was widespread but apparently not abundant, sometimes present in cafés, bazars, abbatoirs, food stores and houses in small numbers and was more directly annoying to man than *M. domestica vicina*. HILL (1921) recorded this fly (*M. humilis*) 2 to 2.5 miles far from any human habitations. LAMBORN (1935-37) noticed that the most prevalent fly collected from the backs of natives in Nyasaland and from their sores was *M. sorbens*. The same fly also constituted 95% of the flies frequenting ulcers and wounds in Uganda according to an annual report published by the Medical Department in that country (1940). The same species was collected from the eyes of children in Egypt (DECOURSEY et al., 1956).

The distinctive characters of the adult and the morphological differences between the two sexes were given by PATTON (1926) and TROFIMOV (1942).

V. MATERIAL AND METHODS

The fact that *M. sorbens* breeds exclusively in human excrement defecated as isolated stools on borders of canals, in alleys, narrow streets, etc., has always created a great difficulty in its breeding in the laboratory.

Successive and continued trials were therefore made to find a suitable breeding method of this species in the laboratory, using a veriety of media both natural and artificial and finally it was found that a mixture of coarse wheat bran and diluted milk (1 water, 2 milk) in the ratio of 1 : 2 is the most satisfactory medium in which the larvae can be reared successfully. As many as 261 larvae could be easily reared in 30 gm. of this mixture, and the adults obtained by this method were quite healthy and normal.

The adults, just after emergence, were transferred into breeding cages and fed on sugar, milk and water; each group of adults emerging on the same day were placed in a separate cage and so each mating couple. By this means it was possible to study their longevity and the duration of the different life processes such as pre-oviposition periods, mating, oviposition and the number of eggs laid by each female etc.

Experiments and observations were conducted under laboratory and controlled conditions. In the former case, room temperature and humidity were recorded by a thermo-hygrograph throughout the time of the experimental work. In the latter case, constant temperatures and humidities were used. The desired relative humidities were obtained from different concentrations of sulphuric acid-water mixtures prepared according to BUXTON (1931), BUXTON and MELLANBY (1934) and SOLOMON (1951). The relative humidities produced by the various acid concentrations were checked before use by means of a tiny hair hygroscope (MELLANBY, 1933).

In longevity the results were statistically analysed according to FISHER (1950). Statistical tables of FISHER and YATES (1948) were used to test the significance of the data obtained.

The ecological observations were primarily conducted in a village called Talbia south west of Cairo near the pyramids. The various types of breeding media prevailing in the village were surveyed and their fly larval population examined. Regularly 3 samples of breeding materials, i.e. human stools, horse manure and fuel cakes (cow and buffalo dung) containing fly larvae were brought to the laboratory and carefully examined at weekly intervals for a period of one year in order to determine their breeding capacity as far as *M. sorbens* was concerned. The flies emerging in such case were identified and counted.

For studying the fly population density the fly grill method of SCUDDER (1947) was used.

Other localities in the country, in towns, and in the desert were frequently visited in the different seasons of the year for studying the breeding media of the fly, its relative abundance, and distribution.

In some experiments (e.g. sex ratio experiments) it was required to immobilise the flies. This was carried out by carbon dioxide. Two small anaesthesia chambers (10 × 2 cm. each) were prepared: an upper chamber with a porous floor and a sliding glass roof and a lower chamber connected by a rubber tubing to the gas cylinder. Flies under investigation were introduced into the uper chamber through a central hole in the glass roof. Exposures lasting from 5 to 30 minutes had no ill effects on the flies and these recovered completely and resumed flight after about 6 minutes. This time of recovery was nearly doubled (11.5 minutes) when exposures were prolonged to 60 minutes.

Ether was also tried as an anaesthetic but was soon given up as all flies died after 5- minutes exposures. In cases with 1-minute exposures, though all the flies recovered after 15.5 minutes, yet 30% of them failed to fly.

For testing colour preference by the adult fly, the following colours were used from various chemical solutions: white, water; violet, haematoxylin 0.001%; blue, copper sulphate 10%; yellow, picric acid 1%; red, eosin 0.5%; brown, iodine 5% (light), 10% (dim).

In another series of experiments, tissue papers of different colours were used for testing the colour response of the fly.

The biological observations and experiments carried out in the course of the present work started in 1953 and continued for about three years.

VI. HABITS OF THE ADULT

M. sorbens, in Egypt, is an almost outdoor species seldom frequenting houses and normally found in the open fields and in such places as the market squares food stores, public slaughter houses, etc. It is also frequently met with inside villages and towns particularly in districts where drainage systems of sewage diposal are not available and promiscuous defecation prevails. Most remarkable is the fact that in the true desert and under its arid conditions *M. sorbens* manifests itself in great abundance and always outnumbers all other Dipterous species. Table I demonstrates this phenomenon; about 60% of the flies caught in the desert (in one series of experiments) were *M. sorbens*. In other countries, however, e.g. in India (Deoras and Jandu, 1943) this species is generally considered as a housefly occurring in great numbers in human habitations.

This fly is more directly annoying to man than *vicina*, although the latter is more abundant. It is more attracted to wounds and ulcers and gathers round eyes, nose and mouth and persistently settles on human body. It has also the predilection of bleeding sites on the skin and constitutes a high percentage among flies feeding actively on fresh animal blood in slaughter houses. Nearly similar habits were

reported by LAMBORN (1937). This author stated that *M. sorbens* may alight on the skin and feed unnoticed, even on regions so sensitive as the face, the slightest break in the surface serving to attract it; also it seems to be especially attracted by the odour of the sweat of uncleanly natives and may be obtained in considerable numbers from their backs and their clothing, and that *sorbens* also has the predilection of legs and feet in bare footed populations, probably due to the liability of these parts to injury.

TABLE 1

The relative abundance of M. sorbens *and other flies in the desert (total of 8 catches)*

Species	Number	Percentage
Musca sorbens	162	60.2
Musca domestica vicina	58	21.5
Musca xanthomelus	17	6.3
Sarcophaga spp.	30	11.2
Wohlfahrtia spp.	2	0.8
Total	269	100.0

M. sorbens seems to prefer bright sites and almost always hover in the sun in the open far from any habitation, and when the sun sets it takes its resting place on twigs, plant leaves and small herbs in the open fields or even on the outside walls of houses.

The fly is very active and the females preponderate around their breeding areas.

This species can withstand a temperature as low as —3°C. for a period of one hour. All flies (males and females) died when subjected to —10°C. for one hour. In the case of *M. domestica*, HAFEZ (1941) stated that the fly could withstand as low a temperature as - 7°C. for six hours but that death occurred when the flies were exposed to -11°C. for three hours. Also FELDMAN-MUHSAM (1944) stated that adult *vicina* cannot endure temperatures below 0°C. for 24 hours, none survives at -10 or -11°C. GREENBERG (1955), working with *M. domestica*, found that 7 out of 13 flies survived the exposure to an average hourly temperature of - 5.0°C. for a period of 44 hours.

The fly, on the other hand, is tolerant to temperatures as high as 45 or 46°C. for one hour. It could also withstand higher temperatures up to 50°C. when the temperature was progressively raised from 35 to 50°C. by 1°C. every 5 minutes. The females, in general were more tolerant than the males and complete and instantaneous death occurred at 51°C. In other flies, e.g. *Musca domestica*, *Stomoxys calcitrans* and *Fannia canicularis*, NIESCHULZ (1933-35) found that the heat stupor which is the prelude to death occurs at 45-46.5°C., 43.5°C. and 39-41°C., respectively.

VII. EMERGENCE

Towards the end of the pupal stage, about 24 hours before emergence, the pupa becomes distinctly darker in colour. The adult emerges by means of its inflated frontal sac or ptilinum, which protrudes in front of the head above the base of the antennae and splits open the puparium. A circular slit appears in the anterior margin of the apparent fifth segment of the pupa and the detached cap splits into two valves by longitudinal fissures close to the anterior spiracular processes of the transformed larva. The fly gradually crawls out of the puparium ridding itself of a delicate sheath, the nymphal sheath (Hewitt, 1914), surrounding it. In a few seconds, sometimes in a few minutes the fly withdraws completely from the pupal case and starts making its way through the overlying soil. This is brought about by alternate inflation and deflation of the frontal sac. The wings, still folded, begin to expand and attain a thin flat and transparent form rigidly supported by the longitudinal veins and cross veins, a process which takes place in about 15 minutes. At low temperatures, e.g. 16°C., this period may be prolonged to about two hours.

Shortly after emergence, the pale colour of the integument gradually darkens and the exoskeleton hardens. This hardening darkening process comes to an end in about one hour.

It may be noted that the just emerged flies seem unable to adhere firmly to the surface upon which they climb, probably due to the pulvilli being not yet completely functional. This difficulty soon disappears by the end of the hardening process.

Time of emergence during the day

In order to determine the time of day at which adult flies emerged, pupae were collected from the standard culture maintained in the laboratory and kept under day-night observations at 1-hour intervals on successive days. This was conducted under room conditions (mainly 28-30°C. and 60-70% R.H.) during June. The results obtained are included in Table II.

It was found, under the given experimental conditions, that the adults emerged between 2200-1100, while no emergence occurred between 1100-2200. Maximum emergence (about 77%), however, was recorded early in the morning between 0400 and 0800 with a peak between 0600 and 0700.

In the case of the common house fly, *M. domestica vicina*, it may be pointed out that almost 70% flies emerged between 0600 and 1200 hours, with a peak lying between 0700 and 1100 hours (Peffly, 1953). In other words, it seems that *M. sorbens* emerges somewhat earlier in the morning than *vicina*, a result which has been also obtained by laboratory observations on both flies.

The same experiments were conducted on cold winter days (e.g. February) and it was found that flies emerged between 1000 and 1550, when the temperature was above 18.9°C. (66°F.). On warmer days, however, emergence started earlier at

TABLE II

Hourly emergence of M. sorbens *in June, 1954. Room conditions (28-30° C. and 60-70% R H.)*

Time	Number of flies emerged	Percentage of total emergence	Average temperature during emergence
2200-2300	12	1	27.0
2300-2400	23	2	26.5
2400-0100	10	1	26.0
0100-0200	33	3	25.0
0200-0300	51	5	25.0
0300-0400	70	7	25.0
0400-0500	141	14	25.0
0500-0600	205	20	24.5
0600-0700	222	22	25.0
0700-0800	212	21	25.5
0800-0900	18	2	26.5
0900-1000	23	2	27.5
1000-1100	10	1	29.0
1100-2200	0	0	30.0

0850, and continued for a longer period till 1850. The peak of emergence was between 1200 and 1400, the time of maximum day temperature. It seemed therefore that during the winter months the number of flies emerging increased with rising day temperature, and decreased again as the temperature became lower.

Duration of emergence

Under room conditions, it was observed that adult flies continued to emerge for about 3 to 8 days according to seasons. In winter (e.g. February), *M. sorbens* continued to emerge for about 6 to 8 days (Table III A). During the summer (e.g. June), emergence continued for a shorter period about 3 or 4 days (Table III B). It was also noticed that most flies emerged on the second and third days in summer and on the third to the sixth day in winter. It may be noted that females outnumbered the males but the reverse took place on the following days.

Under controlled laboratory conditions, nearly similar results were obtained. For instance when the temperature and relative humidity were controlled at 28°C. and 60% R.H. respectively the flies emerged throughout a period of 4 days (Table IV).

In some of the experiments the females outnumbered the males throughout the period of emergence.

Succession of emergence

It was noticed from repeated observations that, among the flies emerging from human stools during the summer, *M. sorbens* was always first. *M. domestica vicina* followed by *Sarcophaga* appeared next. On the other hand, in winter,

TABLE III A

Daily emergence of M. sorbens *Wied. in February, 1954. Room conditions (15.5-21°C. and 50-70% R.H.)*

Days of emergence	Number emerging			
	Male	Female	Total	Percentage
1st.	1	2	3	0.1
2nd.	20	27	47	1.8
3rd.	74	138	212	8 3
4th.	302	414	746	28.9
5th.	617	503	1120	43 6
6th.	261	144	405	15.7
7th.	27	10	37	1.5
8th.	1	1	2	0.1
Total	1303	1269	2572	100.0

TABLE III B

Daily emergence of M. sorbens *Wied. in June, 1954. Room conditions (24-33°C. and 45-85% R.H.)*

Days of emergence	Number emerging			
	Male	Female	Total	Percentage
1st.	3	8	11	10.1
2nd.	19	25	44	40.4
3rd.	21	10	31	28.4
4th.	15	8	23	21.1
Total	58	51	109	100.0

TABLE IV

Daily emergence of M. sorbens *Wied. under controlled conditions (28°C and 60% R.H.)*

Days of emergence	Number emerging			
	Male	Female	Total	Percentage
1st.	4	28	32	6.5
2nd.	74	138	212	43.3
3rd.	137	88	225	45.9
4th.	13	8	21	4.3
Total	228	262	490	100.0

Hylemyia (*Paregle*) emerged first, followed by *M. sorbens*, *Gymnodia*, *Sarcophaga* and *M. domestica vicina* (Table V). *Fannia* rarely emerged from the stools in which case it usually appeared earlier than *Hylemyia*.

TABLE V

Sequence of emergence of different species from human stools.

Species	Days of emergence		
	January	February	June
Hylemyia	1st.	1st.	—
Musca sorbens	3rd.	3rd.	1st.
Gymnodia	6th.	6th.	—
Sarcophaga	7th.	6th.	4th.
Musca vicina	—	7th.	3rd

A parallel phenomenon of ecological succession was also recorded by HAFEZ (1939) working on dung insects. He noticed that the Sepsid, Borborid and Muscid flies appeared first on the dung and were followed by Scarabaeid and Hydrophilid beetles.

Abnormal emergence

Deformed adults were frequently met with in many cases in which the wings were not expanded and remained folded and twisted. Also the body in such individuals was little shrunk. Incomplete emergence also occurred; in such cases the head of the fly or the head and thorax or the body with one wing only appeared. The rest of the body of such incompletely emerging flies remained within the pupal case and shortly afterward the fly died.

Another abnormality occurred in several cases when the adult emerged by its posterior extremity, from the anterior end of the puparium. The abdomen issued first, followed by the thorax and the head. In such cases, the fly could never extricate itself completely from the pupal case. Only in one instance the fly succeeded to withdraw entirely from the puparium but failed to attain its normal dimensions and remained distinctly shrunk. But in most cases of this abnormal emergence, the fly practically remained inside th puparium, the only part of the body showing at the ruptured anterior portion of this puparium, being the hind extremity of the abdomen and the tip of the legs.

From the foregoing observations and experiments, it is clear that adult emergence occurs only within a certain range of time during the day, namely between 10 p.m. and 11 a.m., maximum emergence, however, takes place early in the morning between 4 and 8 a.m. Emergence continues over a period of 3-4 days in summer and 6-8 days in winter. Not all fly species emerge at the same time but in succession; *sorbens* usually emerging first. Abnormal emergence is of frequent occurrence.

VIII. MATING AND OVIPOSITION

Mating

Mating takes place in the superimposed position with the male above the female and facing in the same direction and usually when the flies are at rest. The male grasps the sides of the female with the fore and middle legs, while the hind pair of legs (tibiae and tarsi) supports her firmly across the ventral surface of the abdomen. The process starts by a jump on the back of the female from a short distance. However, the male may alight on his mate in flight, after which the pair comes rapidly to earth in an agitated state. The male caresses the head of the female for sometime by the tarsi of his fore legs and then copulation starts. The female exerts her ovipositor and inserts it into the genital atrium of the male the time the latter bends his abdomen downwards. During the process of copulation, if the couple is startled, the female carries the male on her back and fly together away to safer sites. The male never takes part in this flight, but it is the female which actually departs on wing without separation. At rest each individual of the couple frequently regurgitates its vomits. The duration of the whole act (copulation) may last from 23 to 48 minutes with an average of 34 minutes, at temperatures ranging from 25 to 32°C. In rare cases copulation may last more than one hour. In *M. domestica vicina* coitus lasts 40-45 minutes (Peffly, 1953).

No copulation was observed above 32°C., or below 20°C. On summer days the temperature frequently exceeded 32°C. On these hot days, mating usually took place at such hours as the early morning (9-10 a.m.) or late afternoon (3-5 p.m.f when the temperature was lower than 32°C. In seasons with cool or mild day temperature, copulation was generally observed at the highest temperature range o) the day.

Pre-oviposition period

Flies bred from human excrement began to lay eggs 4 to 9 days (average 7 days) after emergence at room temperature (27°C.), while those reared on milk took one or two days longer. Oviposition, however, was considerably delayed at low temperatures. Thus the pre-oviposition period lasted for several weeks in the late autumn or winter, and oviposition usually did not occur in winter except on days with relatively favourable temperatures above 16°C. (in the middle of the day). The same results were obtained with mated and unmated females.

In other species, e.g. *M. domestica*, the pre-oviposition period lasts 4-8 days after copulation (West, 1951) ; Larsen and Thomsen (1940), working with the same species, recorded 2.67-3 days as a minimum duration after emergence. Greenburg (1955) found that the mean pre-oviposition period was 3.3 days after emergence. Hafez (1941) stated that the flies of *M. domestica vicina* became sexually mature and copulation started 5 days after emergence at room temperature (25-30°C.), and the eggs were laid 2 to 3 days later. Feldman-Muhsam (1944) pointed

out that the females of the same species in Palestine generally begin to oviposit on the 7th day of their life.

Oviposition

M. sorbens normally oviposits on human excrement. Most flies which were sexually mature, settled on the stools immediately after these were introduced into the oviposition cage. Within 10 minutes, it was observed that the number of flies on the stools began to decrease markedly and finally the flies resorted to their normal distribution in the cage.

When young females 1-2 days old were confined to human excrement, the number of flies gaining access to the excrement was of no significance. Therefore it seems, that human faeces is visited by *M. sorbens* for oviposition rather than for feeding.

It was also noticed that old excrement (e.g. 2 days old) did not attract flies, neither for feeding nor for ovipositing. This may be due to the hard crust formed over the stool on aging especially during the summer. If a split is made through such a stool the characteristic offensive smell of the excrement is declared, and the flies are attracted to the smell as soon as it becomes pronounced.

Gravid females oviposit readily on fresh stools of hard consistency as these contain many crevices in which the eggs are laid. The lower crevices, however, situated near the bottom of the excrement deposits are those which are usually chosen by the female for oviposition. On the other hand, in soft stools no cracks in which the ovipositor may be thrusted are available and consequently no eggs are laid. However, oviposition may happen on the third or the fourth day if such stools develop suitable crevices.

Before ovipositing, the female fly walks on the excrement mass seeking suitable crevices and cracks in which the eggs may be laid. The ovipositor then shoots out by the action of the muscular convulsions of the abdomen and the female pushes it as far into the crevice as possible where the deposited eggs get maximum protection from desiccation and actinic light. In most cases the female lays its eggs while in an upside down position with the wings touching the floor and acting as supports.

The process of egg laying usually goes on for about 6 minutes during which the eggs are laid successively. Soon after the oviposition period has terminated the female retracts its ovipositor, restores the normal form of its abdomen and begins to feed voraciously on the excrement till its abdomen becomes somewhat distended. If such a female is disturbed while feeding it does not move away nor shows any response. The same behaviour was observed with ovipositing females. These showed no reaction when alarmed during the process of egg laying.

An oviposition site used by a female is usually chosen by others, either singly or in groups for oviposition. In the latter case, however, an egg cluster is formed.

The female lays 1 to 5 batches of eggs throughout its life (average 3-4 batches). The eggs are closely packed and cemented together in each batch and arranged in

two or three (sometimes more) rows. A single batch contains as many as 32 eggs. Large clusters, however, containing up to 700 eggs or more may be formed by several females. A single female may lay eggs up to 80 eggs during its life. AWATI (1920), in India, stated that *M. promiscua*, a synonymy of *M. sorbens*, never laid more than 50 eggs. A greater number of eggs is laid by *M. domestica vicina* (FELDMAN-MUHSAM, 1944), a single female may lay up to 500 eggs during its life. GREENBERG (1955) in his recent work on *M. domestica* reported that the mean total number of eggs laid by the female was 826, and a single female may lay a maximum of 1688 eggs throughout its life.

Temperature seems to influence the number of eggs laid. This was demonstrated in a series of oviposition experiments at 16, 24, 28 and 32°C. in which mated females were used. In another series the females were accompanied with males. From the results obtained (Table VI) it was found that : (1) no eggs were laid at 16°C, (2) at higher temperatures (e.g. 28 or 32°C.) the number of eggs laid was 4 or more times greater than that laid at 24°C; (3) paired females laid twice or more the number of eggs laid by unpaired ones. PEFFLY (1953) working on *M. domestica vicina* reported a similar finding as the latter; females accompanied with males laid more eggs than those without.

TABLE VI

Effect of temperature on the oviposition of M. sorbens

Temperature in °C.	Number of females used	Average total of eggs per female	
		Female alone	Female + male
16	20	—	—
24	20	6	16
28	20	36	64
32	20	32	66

Also the possible effect of the moisture content of the excrement on oviposition was tested experimentally. In each of the ten tests conducted, 100 ovipositing

TABLE VII

Effect of the moisture content of the excrement on the number of eggs laid by M. sorbens. *Room temperature (27-32°C.)*

Percentage of moisture content	Average number of egg-batches	Average number of eggs (total)
25	0	0
30	1	7
40	3	82
75	1	17
80	0	0

females (accompanied with 100 males) were allowed for 3 hours to choose between human stools of different moisture contents namely 25, 30, 40, 75 and 80%. The maximum number of eggs were laid in stools containing 40% moisture. Above and below this optimum the total number of eggs laid and the number of batches deposited by the females decreased markedly. No oviposition occurred in stools with moisture content below 30% or above 75% (Table VII).

Oviposition on milk

Oviposition may occur on milk cotton pads preferably 2 or 3 days old. The number of eggs laid, however, was relatively small as compared to that usually laid on human excrement; in the former case about 30-40 eggs were laid, while in the latter this number may reach 80.

IX. BREEDING MEDIA

The possible breeding media of *M. sorbens* in Egypt and their relative importance in fly production were studied in several series of laboratory experiments coupled with extensive field observations in the country and in towns.

Laboratory experiments

Preliminary experiments were first conducted to test the attractivity of several kinds of excrement including animal dung and human stools to ovipositing females. These media were exposed to ovipositing females in fly cages (each containing 500 males and females in equal numbers) for 3 hours daily for one week. After each test the eggs were collected and counted.

From the results obtained (Table VIII) it was found that most flies preferred human excrement for oviposition and about 90% of the total number of eggs were

TABLE VIII

The attractivity of various kinds of excrement to ovipositing females of M. sorbens

Animal dung	Average number of eggs laid	Percentage of eggs laid
Human excrement	479	89.4
Horse manure	0	0.0
Donkey dung	0	0.0
Buffalo dung	0	0.0
Cow dung	0	0.0
Calf dung	20	3.7
Camel dung	0	0.0
Fowl manure	0	0.0
Pig dung	37	6.9

laid in it. Pig and calf dung attracted ovipositing females to a very small extent; pig dung, however, proved stronger in this respect. No eggs were laid in the other kinds of dung tested, namely horse and fowl manure, the dung of cow, buffalo, donkey, and camel.

When the above materials were offered separately to ovipositing females, the same results were obtained, but it was noticed that oviposition did occur in cow and buffalo dung. The same observation was reported by PEFFLY (1953).

After obtaining these results, other series of experiments were carried out to study the fly breeding capacity of the above media to which was added another kind, i.e. fuel cakes made of a mixture of cow and buffalo dung. In each experiment quantities of equal weight (1 kilogram each) of human excrement or animal dung were brought to the laboratory after being subjected in the open to ovipositing flies for 24 hours. Fuel cakes, however, were not used by weight but by number, 10 cakes being used in each test. Ten experiments were conducted every month throughout the year. The flies emerging from these media were identified and counted.

The results obtained are in full agreement with those obtained from the oviposition experiments, both revealing the fact that *M. sorbens*, under conditions

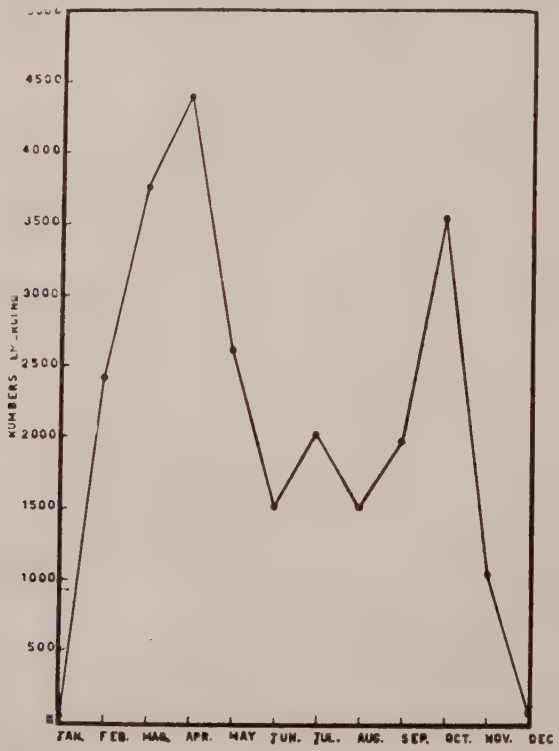

FIG. 1: Seasonal abundance of *M. sorbens* emerging from 1 kg. of stools.

prevailing in this country, breeds almost exclusively in human excrement in the form of isolated stools. Pig dung and fuel cakes, however, produce the fly in relatively very small if not negligible numbers. Other kinds of animal dung are not at all suitable as breeding media for this species. It is also clear that the fly breeds all the year round, most abundant in the spring and autumn and very poorly represented in December and January (Fig. 1). Nearly similar findings were reported by PEFFLY (1953). PATTON (1920) and JACK (1931), however, mentioned that the fly breeds chiefly in cow and buffalo dung. HAFEZ (1941) made the same statement but added that this species also showed a great attraction to human excrement.

It may be noted that several fly species, besides *Musca sorbens*, emerged from the various breeding media in the above experiments. *M. domestica vicina* was the most dominant of all flies, emerging in extreme abundance from horse manure and in varying degrees from other kinds of animal dung. This species also emerged from human stools and fuel cakes. Other species of *Musca*, i.e. *M. crassirostris*, *xanthomelus* and *vitripennis*, emerged in relatively small numbers from fuel cakes, the first species however was the most dominant of all. *Paregle cinerella* was produced in great numbers from human stools, cow and buffalo dung. *Sarcophaga carnaria*, *S. hirtipes*, *S. striata*, *Gymnodia tonetrui* and *Muscina stabulans* emerged from human stools; the latter species was also produced from horse manure. *Stomoxys calcitrans* was obtained from horse manure and fuel cakes in small numbers.

Field observations

Field observations on the possible breeding grounds of *M. sorbens* in Egypt were conducted in the region of Cairo and in many villages throughout the years 1953-1955. Regular visits were made to 4 districts of the city of Cairo (Ghamra, Imbaba, Boulak El-Dakrour and Demerdash); 11 villages, 5 near Cairo (Abou Roash, Gabal Asfar, Abou Atata, Harb and Talbia), 2 in Upper Egypt (Nazla and Karoun) and 4 in Lower Egypt (Sindbis, Barada, Quaranfil and Aghour El Kubra). The sites of investigations in these areas included latrine dumps, isolated human stools, sewage disposal farms, horse and donkey stables, pig sties, cow and buffalo byres, camel sheds, fuel cakes, and house refuse or garbage. The results of repeated inspection of these breeding grounds are summarised in the following :

(1) LATRINE DUMPS : These consisted of waste organic material, human excreta and waste water or in other cases formed by dumping human faeces removed from cesspits in houses. Thorough and repeated search for the larvae of *sorbens* in these dumps revealed their entire absence. *M. domestica vicina*, on the other hand, breeds actively in this medium. PEFFLY (1953) reported the occurrence of *M. sorbens* larvae in latrine dumps and stated that they were numerous during the summer.

(2) ISOLATED HUMAN STOOLS: Defecation in the open is of common occurrence both in towns and in villages particularly in such areas where sanitary arrangements and drainage systems are inadequate if not absent. In almost all cases, these isolated

stools when examined, were found positive and usually teeming with prodigious numbers of *sorbens* larvae.

While carrying these observations the percentage of stools infested with larvae of *M. sorbens* in positive samples (stools containing any fly larvae) was determined. In the breeding season (e.g. in April) about 89% of the positive stools examined contained *sorbens* larvae. Other fly larvae commonly found in the stools were those of *Sarcophaga* and *Paregle*.

(3) Sewage disposal farms : The sewage disposal farm of the city of Cairo, about 22 kilometres outside the city at Gabal Asfar and the sewage farm of Abou Roash, about 11 kilometres from Giza town were frequently visited. In both farms the drying beds where the sludge is accumulated and later used as a fertilizing manure, were repeatedly investigated. Tremendous numbers of larvae and pupae of *M. domestica vicina* were found but none of *M. sorbens*. Flies emerging from samples of such breeding medium, taken to the laboratory were all of the former species.

(4) Horse and donkey stables : Horse and donkey dung either in the form of isolated droppings or accumulations inside and outside stables or mixed with litter and urine to form animal bedding was repeatedly inspected and in all cases the dung harboured no *sorbens* larvae; all *Musca* larvae present were those of *vicina*.

(5) Pig sties : *M. sorbens* was found to breed in pig dung accumulated in sties and scattered all over the place. These sties which were extremely filthy and with no sanitary care usually contained flies and fly larvae of this species, but relatively in much small numbers than those of *M. domestica vicina*.

(6) Cow and buffalo byres : The dung of these animals may be distinguished into 3 main breeding sites : (*a*) droppings mixed with litter and urine to form animal bedding on the floor of the byre; (*b*) compost piles, large accumulations of cow and buffalo dung exposed in the open; (*c*) fuel cakes made of one or both kinds of dung. Animal beddings and compost piles were always negative containing no larvae, whereas fuel cakes made mainly of buffalo dung was found to contain *M. sorbens* larvae in moderate numbers.

(7) Camel sheds : Camels are somewhat widely distributed in the country and semi-arid areas and in many cases there are special stables fitted exclusively for their keeping. Investigations of these animal sheds showed that the dung was worked into the food remains and urine on the soil forming a more or less continuous layer or bedding which was found to be a favourable breeding medium for *vicina* but not for *sorbens*.

(8) House refuse : In towns, house refuse is usually piled up in large heaps or public dumps whereas in villages it is scattered in small accumulations. In both cases, careful search for *sorbens* larvae in such breeding grounds revealed their complete absence. *M. domestica vicina* larvae, on the other hand, occurred in tremendous numbers.

The results of the foregoing field observations and breeding and oviposition experiments clearly demonstrate that *M. sorbens* in Egypt breeds chiefly in human

excrement (isolated stools) whose attractivity to ovipositing females highly exceeds that of any other breeding substance. Unfortunately, these stools are always available to flies especially in the country and in many urban districts which lack adequate sanitary arrangements and drainage systems and where the habit of defecating in the open prevails especially among the rural population. The fly also breeds to some extent in pig dung and fuel cakes (cow and buffalo dung). The contribution of these media to the production and prevalence of this species in Egypt should not be underestimated. These media, though far less attractive than human excrement to ovipositing females, yet their wider distribution, abundance and immediate availability to flies, may compensate for this disadvantage and the total number of flies produced by these media may be really considerable. The importance of these breeding media with regard to *sorbens* have been emphasized by a number of workers in various parts of the world (vide historical review, p. 85).

Perhaps one of the remarkable phenomena is that *M. sorbens*, and other fly species as well, breed in definite kinds of materials persistently avoiding others. This marked selectivity on the flies' part may be due, as THOMSEN and HAMMER (1936) and HAFEZ (1939) have pointed out, to differences in the chemical and biological composition of the various kinds of dung or in the temperature and humidity conditions of the dung or to certain tactic reactions of the adult fly.

X. SEASONAL PREVALENCE

Inside the villages

Field studies on the relative population density of *M. sorbens* throughout the year weri conducted in Talbia village near Cairo. SCUDDER'S grill (1947) was used. This was one yard square and divided into quadrants, the wooden stripes were tipped with black paint at alternate ends in groups of three, to make counts easier when the flies settle in large numbers on the grill. The grill was placed at the concentration centres of the fly. These were regularly inspected and located in the village. Fly concentration centres, e.g. human stools, latrine dumps, date and sugar cane wastes (in season), compost piles, slaughtering sites, garbage refuse together with water wastes, etc., were more abundant inside the village in alleys, narrow streets and squares.

Outdoor counts were made weekly in a year's period, and the arithmetic mean was obtained from the 4 maxima of all the counts and was considered to be as the index throughout the area (SCUDDER, 1947). At each grill placement the highest count was either the first or the second.

Diurnal variations in the fly density did occur throughout the day, and the high midday temperature seemed to cause the flies to disperse making it too difficult to continue sampling, as it was also emphasized by SCUDDER (1947). On the other hand, periods of maximum counts occurred within the midday temperature

in cooler weathers. Highest counts mostly occurred at about 30°C. on days with higher maximum temperatures; and close to the maximum day temperature when the latter was below 30°C. Therefore counts were made earlier in the morning in the summer (8-9 a.m.) and later in the winter (12-2 p.m.). Intermediate times in the spring and autumn were chosen (10-12 a.m.). The grill index during the late afternoon usually showed persistent fall even when the temperature was within the optimum range. Similar results about house flies were obtained by MADWAR and ZAHAR (1951), and Holway et al. (1951) who also stated that this fall was probably associated with approaching sunset in as much as the drop tended to occur later in summer than in winter months.

The flies settling on the grill were largely a mixture of *vicina* and *sorbens*. After each fly count, in a given concentration centre, fly catches were made and the relative proportion of one fly to the other was determined. From this proportion

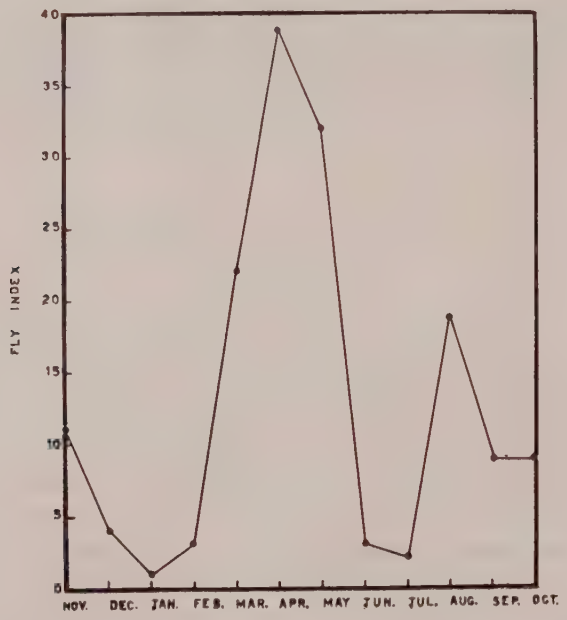

FIG. 2: Fly index of *M. sorbens* throughout the year Nov. 1954 - Oct. 1955.

the population density of *sorbens* on the grill was then calculated. Other species frequented the concentration centres but in small numbers which never affected the net results when neglected. The mean monthly counts or indices for *sorbens* and *vicina* in Talbia are summarised in Figure 2.

It is clear that *sorbens* as compared to *vicina*, under the given experimental conditions, shows itself in small numbers. These, however, are highest in the spring, mainly in April and in August, and lowest in January and July. *Vicina* has practically the same seasonal fly abundance as previously emphasized by HAFEZ (1941), HOLWAY et al. (1951) and MADWAR and ZAHAR (1951). It was also noticed, in both species, that the autumn or August peak is distinctly smaller than that of the spring.

In the open fields and deserts

Although *sorbens* always occurred in small numbers within huge congregations of *vicina* inside the village, yet it manifested itself in greater abundance than *vicina* in the open fields. The relative proportion of *sorbens* to *vicina* was determined from counts made throughout the year 1955 in the open fields at Talbia, at about 2-3 kilometres far from any residential area or attractive foci inside the village. The results of monthly mean counts clearly demonstrate that *sorbens* outnumbered *vicina* in the open fields all the year round sometimes to the ratio of 12 : 1. A steady increase in the numbers of *sorbens* started from January and continued till May when the highest peak was reached. A somewhat smaller peak, however, occurred in August (Figure 3).

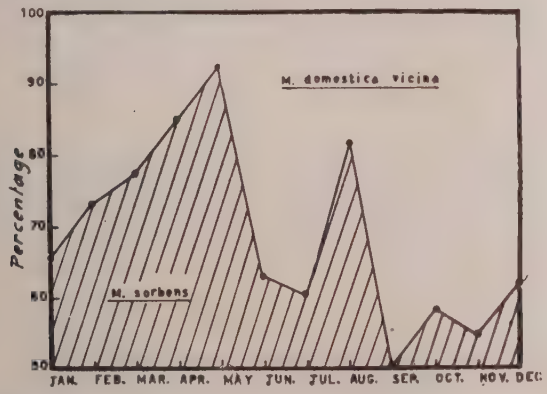

FIG. 3: Percentage of *M. sorbens* and *M. domestica vicina* in fly catches in the open fields throughout the year 1955.

Catches were also made in true desert areas, several miles away from human campings and cultivation; under such arid conditions *M. sorbens* outnumbered all other Dipterous species and constituted about 60% of the flies in the desert. The females outnumbered the males. Similary, *sorbens* was abundant in Ataka area in the eastern desert 1500 feet (or higher) above sea level. The fly was also most prevalent in May and August.

Fly congregations on diseased eyes

Weekly fly catches from children diseased eyes in villages were made in Talbia village throughout 1954-1955. Monthly mean counts were obtained and the percentage of *sorbens* and *vicina* were then calculated. From the results, it was clear that both species of *sorbens* and *vicina* occurred on diseased eyes. *M. sorbens*, however, dominated *M. domestica vicina* throughout the spring and early and late summer, the ratio reaching 8 : 1 in June (Figure 4). In November, December and January, however, the reverse took place, *vicina* showed itself in greater abundance than *sorbens*.

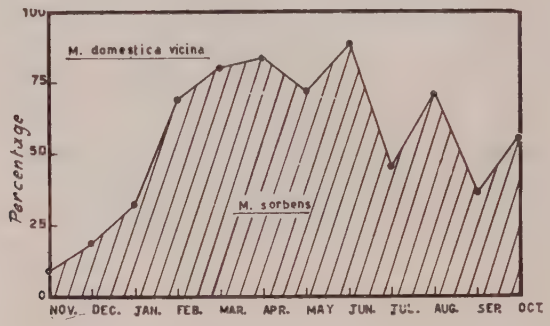

FIG. 4: Percentage of *M. sorbens* and *M. domestica vicina* on diseased eyes throughout the year Nov. 1954 - Oct. 1955.

The above studies on fly population densities throughout the year inside villages, in open fields and deserts and on diseased eyes have clearly demonstrated that *M. sorbens* is found all the year round but generally show two peaks of seasonal abundance one in the spring and one in August. On diseased eyes, however, the number of *sorbens* is highest in June. The remarkable preponderance of *sorbens* in the open fields and deserts is probably due to the wild habit of this species, possibly migrating several miles from its breeding grounds to such open areas. Its abundance in the open fields may be also partly attributed to the wide distribution of cow, buffalo dung and fuel cakes which all provide numerous and extensive sites for ovipositing females. Furthermore, the occurrence of *M. domestica vicina* in smaller numbers in the desert and open fields may be due to the domestic nature of this fly being almost always associated with man and human habitations.

XI. LONGEVITY

Under room conditions (24-30°C. and 50-60% R.H.) the average longevity of the male and female flies was about 18.5 and 21 days respectively.

The longevity of the fly was studied at different temperatures, e.g. 24, 28, 32 and 36°C., humidity being kept constant at about 50% R.H. The sexes were tested separately and 10 individuals were used for each test. Ten tests were conducted at each temperature. At 28 and 32°C., additional tests were made in which one sex was accompanied with the other. In all cases the flies were provided with sugar, milk and water. The results are given in Table IX and Figure 5. It was found that :

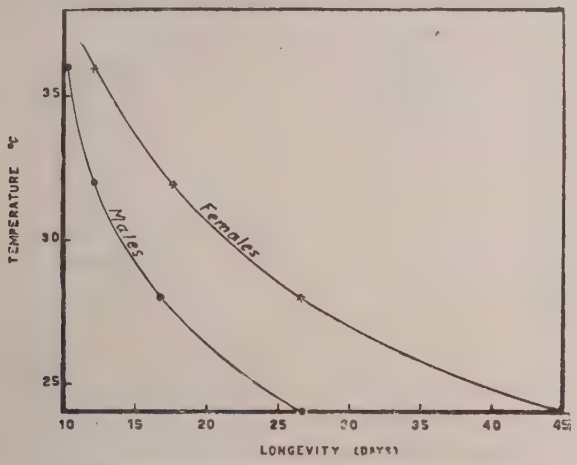

FIG. 5: Effect of temperature on longevity (pure).

1. — The longevity of both sexes was longer at lower temperatures and shorter at higher temperatures. Thus the male and female flies lived about 27 and 35 days (average) respectively at 24°C. and about 10 days (average) at 36°C.

TABLE IX

Effect of temperature on the longevity of M. sorbens

Temperature in °C.	Longevity in days					
	Males			Females		
	Minimum	Maximum	Mean ± s.e.	Minimum	Maximum	Mean ± s.e.
24 (pure)	18.0	36.0	26.8±0.77	28.0	45 0	35.0±0.62
28 (pure)	13.5	24 0	16.9±0.42	14.0	26.5	18 8±0.60
28 (coupled)	12.0	21.5	16.3±0.51	14.5	23.0	17.6±0.48
32 (pure)	8.0	16.0	12.1±0.49	11.0	17.5	14.0±0.27
32 (coupled)	6 0	15.0	11.4±0.46	8.0	15.5	11.9±0.35
36 (pure)	6.0	12.0	10.1±0.23	6.0	12.0	10.4±0.21

2. — The increase in longevity in both sexes was rather gradual from 36 to 32°C. and from 32 to 28°C. but sudden and most marked from 28 to 24°C. when the longevity was nearly doubled in the female and little less than doubled in the male.

3. — The males were shorter lived than the females; this was most evident at 24°C.

4. — Longevity also decreased but slightly when the flies were coupled in the cage; for example at 32°C. the coupled flies lived for about one day (in the male) or two days (in the female) less than the pure ones.

It may be pointed out that owing to lack of equipment it was not possible to test the longevity at temperatures lower than 24°C. From the results obtained it is very likely that *M. sorbens* in nature may live for a few months in winter and for a few days in summer, under Egyptian climatic conditions. Awati (1920), working in India with *M. promiscua* (a synonymy of *sorbens*) found that the average longevity of this fly was 16 days. *M. domestica vicina* on the other hand seems a longer lived fly as compared to *sorbens*. Thus at 27 and 35°C. the longevity of *vicina* at 60% R.H. according to Feldman-Muhsam (1944) was 32 and 17.6 days, respectively. These figures are distinctly higher than those of *sorbens* at nearly the same temperature and humidity. Hafez (1941) succeeded to keep flies of *M. domestica vicina* alive in January for 70 days. In case of *M. domestica*, Griffith (1908) was able to keep a male fly alive for sixteen weeks. Jepson (1909) succeeded in keeping alive for eleven and half weeks flies which had been reared in captivity in February. Hewitt (1914) stated that he never succeeded in keeping flies alive in captivity for a longer period than seven weeks. Glaser (1923) pointed out that on the most suitable foods the longevity of *M. domestica* varies from 2 to 57 days, with an arithmetical mean of 20 + days. The longest-lived individuals had an arithmetical mean of 34 + days. He also stated that in general females lived longer than males. Similarly, Greenberg (1955), working with *M. domestica*, stated that in the majority of cases the female outlived the male, the longevities recorded for the male and female were 20.3 and 25.3 days respectively (at a temperature about 25°C.).

Effect of diet on longevity

The possible effect of diet on the longevity of the fly was tested in some preliminary experiments. Human excrement, buffalo dung, lactose, sucrose, water and milk were offered separately to the fly as food. Twenty flies of both sexes were used in each experiment. Temperature and relative humidity were kept constant at 32°C. and about 50% respectively.

From the results obtained (Table X) it was found that the shortest longevity was recorded when human excrement or buffalo dung were supplied as food, the fly could not live more than about one day. When human excrement was mixed with water, longevity was prolonged to about two days. The latter period was also obtained using lactose, sucrose or water each given at a time. By offering milk

(diluted) the fly lived for about 5 days. The longest period of life (about 13 days) however, was recorded when the fly had access to either milk plus sugar plus water or to sugar plus water.

TABLE X

Effect of diet on the longevity of M. sorbens

Diet	Average longevity in days
Human excrement	0.9
Buffalo dung	0.9
Lactose	1.8
Sucrose	2.2
Water (plain)	2.0
Milk	5.3
Human excrement + water	2.0
Sucrose + water	13.5
Milk + water + sucrose	13.0

It seemed, therefore, that human excrement, buffalo dung and probably other kinds of animal dung do not serve as food for the fly, most likely they serve only for oviposition. Sugar, on the other hand, was important for life maintainance of the fly. Proteins (milk) apparently introduced no effect upon the longevity when added to sugar. However, in the case of *M. domestica*, ROUBAUD (1922) and GLASER (1923) pointed out that the flies require both sugar and protein substances and that the females fed on either without the other will not produce eggs. Similarly, KOBAYASHI (1934), working with *M. domestica*, found that saccharose or soluble starch was necessary for longevity, and proteins for the maturation of the ovary. Also DERBENEVA-UKHOVA (1935), working on the same species, stated that when fed on a 20%. solution of sugar the flies survived, but the ova did not develop; full sexual development was completed in five days on a diet of milk. LODGE (1918) found that water was very necessary and without it flies of *M. domestica* could not live more than 48 hours.

Effect of starvation upon longevity

Similarly, the effect of starvation on the longevity of flies was tested in some preliminary experiments in which the flies were offered no food since the time of their emergence. The two sexes were tested separately and 20 flies of each were used in each test at 24, 28, 32°C. and 30 or 70% R.H. Another series of control experiments using normal unstarved flies was conducted under the same conditions.

Unstarved flies lived for about 34, 18 and 13 days in the case of females or 25.5, 16 and 11.5 days in the case of males at 24, 28 and 32°C., respectively, and

30% R.H. On starvation, the longevity of the female was only about 30, 21 and 15 hours and of the male 44, 25 and 18 hours at the same temperatures and relative humidity mentioned above in the order named. The results are shown in Table XI.

TABLE XI

Effect of starvation upon the longevity of M. sorbens

Temperature in °C.	R.H.	Time of death of starved flies in hours	
		Male	Female
24	30	44	30
28	30	25	21
32	30	18	15
28	70	28	24
32	70	20	16

It is clear that starvation had a detrimental effect upon life of the fly, and soon died few hours after emergence unless food and drink were available. Longevity of starved flies was somewhat shorter at lower humidity, thus at 30% R.H. it was about 3 hours less than at 70% R.H. when the temperature was 28°C. Also starved females lived shorter than starved males.

Similarly, the longevity of *M. domestica* was seriously affected and the flies died within 1-2 days in summer when reared in captivity without food (GLASER, 1923). The longevity of *M. domestica vicina* was studied by FELDMAN-MUHSAM (1944). This author stated that when flies were kept for one day at room temperature without food, 12% of the females and 62% of the males died; after one additional day without food another 16% of the females and 27% of the males died. Almost all the surviving flies died on the third day of starvation, though some survived up to the fourth day under optimum conditions of temperature and humidity.

XII. FLIGHT RANGE

The range of flight of *M. sorbens* was tested in the following way : about 10,000 flies marked with red acetone paint sprayed over their bodies while under carbon dioxide anaesthesia, were released at a certain point in the open field half way between two villages, Koniisa and Tersa (Giza province).

Search for these flies was made at varying distances from the release point mostly among fly congregations on diseased eyes of children. Marked flies were recovered 1-2 hours after their release at a distance of about 2 kilometres far from the release point. On the following days (2nd and 3rd) some other flies were captured still further at a distance of about 3 kilometres.

No further data were obtained since the procedure necessitated much labour and co-operation of technical staff which were not available under the conditions of the present work. However, it seemed quite possible that *M. sorbens* could travel several miles further more. This may explain the occurrence of the fly in the desert far away from its natural breeding grounds. Camel and wild rabbit dung commonly found in the desert were frequently inspected and were found to contain none of the fly larvae of *M. sorbens.*

The flight range of the common house fly was studied by a number of authors. For instance BISHOPP and LAAKE (1919) releasing 80;000 artificially coloured flies pointed out that marked specimens of *M. domestica* were recovered from as far as thirteen miles away from the centre of release. The same authors (1921) from a release of a total number of flies of 234,000 found that *M. domestica* was found six miles from the release point in less than twenty-four hours. DERBENEVA-UKHOVA (1942), however, found the flight range of *M. domestica* was not usually more than 1,150 feet. More recently WOLFINSOHN (1953) releasing flies of *M. domestica vicina* marked with coloured dust and radioactive phosphorus stated that with increasing distance the number of flies recovered decreased rapidly and that flies tended to go with the wind rather than against it. QUARTERMAN et al. (1954) mentioned that wild flies of *M. domestica* released after being marked with radioactive phosphorus (by feeding them on milk containing P-32) were recovered under rural conditions up to 5 miles from the release points in less than twenty-four hours after release; flies apparently dispersed at random over an area 8 to 10 miles in diameter, with few individuals being trapped up to 10 miles from the release point. The same authors (1954) studied the dispersal of *M. domestica* under urban conditions using as marking material a combination of radioactive chemicals incorporated in their food and a variety of dyes dusted on them before release; the majority of the marked flies were trapped within half a mile from release points although approximately one-third of the re-captured flies were trapped more than a mile away in one test, and the flies were recovered as far away as 7.6 miles.

XIII. SEX RATIO

The ratio of one sex to the other in *M. sorbens* was nearly 1:1 in flies emerging from either artificial or natural breeding medium. The females being slightly in excess. Occasionally, however, there was a departure from the normal expectancy and the males outnumbered the females. In flies emerging from human stools (in nature) the males preponderated in summer in June and July although the reverse took place and the females outnumbered the males in rare cases particularly in August. In the other months of the year although more females emerged than males yet the differences were relatively small, except early in winter (December) when the females were in the majority. In *M. domestica vicina* emerging from horse manure the sex

ratio was practically the same as that of *sorbens*, being nearly 1:1 with slight preponderance of one sex or the other during the seasons of the year.

The sex ratio in fly catches made inside the village in the vicinity of breeding areas of the fly, in the open fields away from the village or any residential area, on diseased eyes and in the desert gave nearly similar results and there was usually a preponderance of females all the year round being 80, 73, 79 and 67%, respectively. The male catches were always of a lower ratio. The same was true in the case of *vicina* and the females were much in excess.

The foregoing results on the sex ratio of *M. sorbens* under such different conditions of fly congregations are summarised in Table XII.

TABLE XII

Sex ratio of M. sorbens *under different conditions*

Condition	Percentage of each sex	
	Male	Female
Flies emerging from artificial media	48.2 (about 50)	51.8 (about 50)
Flies emerging from natural media	44-55 (about 50)	45-56 (about 50)
Fly catches inside the village	20	80
Fly catches in the open fields	27	73
Fly catches on diseased eyes	9-34 (about 21)	66-91 (about 79)
Fly catches in the desert	33	67

Therefore, it is clear that flies of *M. sorbens* emerged from their breeding media, either artificial or natural, in almost equal numbers, but when captured where they normally occurred in nature the females were always in the majority.

Similarly, FELDMAN-MUHSAM (1944) working with *M. somestica vicina* in Palestine found that males and females in laboratory experiments emerged in equal numbers. However, she stated that the sex ratio varied throughout the year in one of the localities investigated and the captured flies showed a preponderance of males during the summer and of females in winter, while both sexes were nearly equal in autumn (November) and spring (April).

KATAGAI (1935) referred the irregularities in the sex ratios throughout the year including the excess of the females from November to April, to the greater ability of the females to survive during this period of the year. WEST (1951) has attributed this phenomenon partly to the greater longevity of the females and also to their frequent appearance in the breeding areas for oviposition. The higher counts of males in certain seasons, however, e.g. early summer ensures the fertilisation of all the females present.

Considering the size of the fly in the catches undertaken throughout the year it was observed that there seemed to be a relation between the size and the sex ratio; among undersized fly populations the males were more numerous and vice versa.

West (1951) emphasized the correlation between the sex ratio and the size of *M. domestica* in nature as a function of its larval nourishment. He stated : "In nature, the sexes are usually about equal, but occasionally there is considerable departure from the normal expectancy. It has been my observation that when the size of the average adult, in random sampling, runs small, the males will be more numerous, while if the average fly captured is of superior weight and size, such is never the case. This would appear to be in part an expression of the amount of food available during the larval state, especialy so when nourishment is insufficient".

XIV. COLOUR PREFERENCE

The preference of *M. sorben* to colours of different wave lengths was studied experimentally in two different ways. In the first, the flies were tested singly and the response of each to a given colour was studied; in the second groups of flies were offered the chioce of resting on coloured surfaces and their response was recorded.

Response of individual flies

Several batches of flies 2-3 days old, 10 of each sex, were used for each experiment in which each individual fly was then required to make 10 test trips towards a certain light. The fly was therefore kept in a cylindrical glass tube 12 cm. long and about 1.5 cm. in diameter, closed at both ends and provided with a wide pore stoppered by a cork half way its length. The tube was carried horizontally and light came to each end through a small cylindrical tan 8 cm. in length provided with glass sides and filled with the appropriate colour solution of certain chemicals. A 40-watt electric bulb was held before each tan. The two light sources were turned on alternatively at intervals of 15 seconds and the frequency of the fly to each end of the tube was recorded. The colours used were : white, violet, blue, yellow, red and brown.

Table XIII

The frequency of M. sorbens *to different light colours*

Colour	Frequency	
	Male	Female
White	100	100
Violet	83	87
Blue	70	78
Yellow	52	53
Red	74	80
Brown (light)	7	9
Brown (dim.)	0	0

The flies used were reared on milk-bran mixtures, at 28°C., and fed on milk sugar and water. The experiments were conducted under room conditions 25-28°C. and 50-60% R.H.

The frequency of the fly towards each colour in 100 test for each sex is given in Table XIII. It is clear that *M. sorbens* readily responds to white light more than any other light. The violet ranked next to white, while the red, blue and yellow followed in the order named. The brown shades were the least preferred by the fly, the dim shade was consistently avoided. The female showed a higher response to all light colours than the males.

Flies resting on coloured surfaces

A cage 30 × 30 × 50 cm. was used. All the sides of the cage were lined with black drawing paper except the front sliding glass pan (30 × 50 cm.). In the back of the cage there was a hole for observations. The glass pan, in front, was divided into 8 equal quadrangular areas covered (externally) with tissue papers of different colours. The colours used were : white, violet, blue, green, black, yellow, red and brown.

Only females 2-3 days old were used; 50 of these furnished the experimental number for each test. During the time of the experiment the coloured face of the cage was made opposite to the window. The flies frequenting each colour were counted at 2-minute intervals, ten times successively. The fly that left and returned to alight on any particular colour was counted twice.

From the results obtained (Table XIV) it was found that the greatest majority of the flies used were attracted to the white patch receiving direct day light, while very few were recorded on the other colours.

TABLE XIV

Counts of flies resting on 8 different colours

Colour	Frequency
Black	0
White	136
Violet	1
Blue	9
Green	1
Yellow	6
Red	1
Brown	0

When the white colour was made unavailable to the flies (e.g. by covering the white patch by black paper) thus leaving them to choose between the violet,

blue, green, yellow, red and brown it became clear that the flies had a distinct preference to lights of short wave lengths, Table XV. The violet followed by the blue attracted the flies most, while the remaining colours particularly the brown were distinctly inferior.

TABLE XV

Counts of flies resting on 6 different colours

Colour	Frequency	Colour	Frequency
Violet	18	Yellow	5
Blue	14	Red	6
Green	6	Brown	4

For an accurate comparison, the ratios obtained between the above frequencies on the six colours used are given in Table XVI, to indicate directly the relative attractivity of each colour.

TABLE XVI

Ratios obtained from a comparison when six colours were used

Colour	Violet	Blue	Green	Yellow	Red	Brown
Violet	1.0	0.8	0.3	0.3	0.3	0.2
Blue	1.3	1.0	0.4	0.4	0.4	0.3
Green	3.0	2.3	1.0	0.8	1.0	0.7
Yellow	3.6	2.8	1.2	1.0	1.2	0.8
Red	3.0	2.3	1.0	0.8	1.0	0.7
Brown	4.5	3.5	1.5	1.3	1.5	1.0

Another series of experiments was conducted in which the fly was offered the choice of two attractive colours at a time and the flies resting on each colour were counted. The alternatives used were : violet-blue, violet-green, violet-yellow, violet-red, violet-brown, blue-green, blue-yellow, blue-red, blue-brown, green-yellow, green-red, green-brown, yellow-red, yellow-brown, and red-brown.

The ratios obtained in such a comparison when two colours only were used are summarised in Table XVII.

The results obtained have again emphasized that *M. sorbens* seems to have a definite order of preference for the spectral lights. Lights of short wave lengths, i.e. the violet and the blue were much more attractive to the fly. The brown was the least preferred. However, the bright shades of the colours used were more favoured by the fly than the darker shades of other colours irrespective of their wave lengths.

The colour preference in houseflies was previously studied by a number of workers. GALLI-VALERIO (1910) found that *domestica* flies preferred clear light

colours in the following order : clear green, rose, clear yellow, azure, clear red, dark grey, white, dark red, pale grey, dark yellow, dark green, red, orange, clear brown, pale rose, very clear green, black, blue, pale violet, dark brown and lemon yellow. AWATI (1920) in his studies on the attraction of houseflies to different colours,

TABLE XVII

Ratios obtained from a comparison when 2 colours only were used at a time

Colour	Violet	Blue	Green	Yellow	Red	Brown
Violet	1.0	0.5	0.4	0.5	0.2	0.2
Blue	2.1	1.0	0.4	0.7	0.3	0.1
Green	2.3	2.4	1.0	0.4	0.7	0.2
Yellow	2.1	1.5	2.5	1.0	0.9	0.2
Red	6.7	4.0	1.5	1.1	1.0	0.3
Brown	4.5	10.3	6.3	6.3	3.0	1.0

noticed that yellow had the greatest attraction, red and violet the least; blue, green and orange were intermediate. FREEBORN and BERRY (1935) working with *M. domestica* found that houseflies, when given a choice of colour, will show a marked preference for one colour over another. For instance orange was not distinguished, apparently from five other colours ranging from light blue, through jade green, aluminum, canary yellow and light gray.

WATERHOUSE (1948) studied the effect of colour on the numbers of flies of *M. domestica* resting on painted surfaces in a Peet Grady chamber. He found that lighter colours were less attractive than darker ones. Red was most commonly preferred while sky blue and white were the least chosen.

WIGGLESWORTH (1953) stated that when light of equal energy was compared, the ultra-violet was said to be the most effective and the most luminous region in the visible spectrum, and there was a good evidence that insects were less sensitive to the red end and more sensitive to the violet end of the spectrum. Similarly, it was emphasized by ROEDER (1953) that all the wavelengths of the spectral lights were not equally stimulating, the region of blue, blue green and ultraviolet being the most effective.

XV. SUMMARY

Biological and ecological observations have been conducted on *Musca sorbens* in Egypt. This fly is an almost outdoor species, fairly abundant in the country, in towns and in the open desert. In the latter case, it outnumbers all other fly species. It is a great nuisance to man resting on his body particularly the face and eyes and possibly acting as the main insect vector

of eye diseases in Egypt. To the unexperienced eye, this species is easily mistaken for the common house fly *Musca domestica vicina* from which it is distinguished by the presence of 2 (instead of 4) dark longitudinal stripes on the thorax.

Emergence

The fly usually emerges between 2200 and 1100 hours (summer), most of the flies, however, emerge between 0500 and 0800 hours. In cooler seasons emergence occurrs later between 0850 and 1850 hours with a peak at 1200 to 1400 hours (winter). Emergence continues over a period of 3-4 days in summer and 6-8 days in winter. *M. sorbens* is usually the first among flies emerging in succession from human stools.

Mating

Mating lasts for about 34 minutes (average), but none was observed above 32°C. or below 20°C. The female lays its eggs about 7 days after emergence (room conditions). A single female may lay up to 80 eggs, in 4 batches (throughout life). More eggs are laid at 32°C. than at lower temperatures.

Oviposition and breeding

The chief oviposition and breeding medium of *M. sorbens* in nature is human excrement (isolated stools most suitable with 40% moisture content); breeding and oviposition to a very small extent, however, may occur in cow or buffalo dung (or a mixture of both; fuel cakes) and pig dung. The fly breeds all the year round with two peaks of seasonal abundance; one in the spring (April) and one in August. The fly is more abundant in districts deprived of or with inadequate drainage system of sewage disposal. Oviposition may occur on milk (pads).

Longevity

The female fly lives 21.0 days and the male 18.5 days under room conditions (24-30°C.; 50-60% R.H.). Longevity is longer at lower temperatures (about 31 days at 24°C.) than at higher ones (about 10 days at 36°C.). Mated individuals are of lower longevities. The males are shorter living than the females (27 and 35 days at 24°C., respectively). Sucrose is essential for the adult life, proteins seem to be of no great importance for lengthening the span of life. Flies when kept in captivity without food die in about 24 hours at 28°C.

Sex ratio

The sex ratio is about 1:1 among flies emerging from artificial or natural breeding media, but the females usually preponderate around breeding and feeding areas inside the village, in the open fields, deserts and on diseased eyes.

Flight range

Flies were recovered in an area about 6 kilometers in diameter (3 kilometers from the release point).

Colour preference

The adult fly was attracted to colours of short wave lengths (the violet) more than to those of long wave lengths (the yellow and red), the brown was the least preferred. However, the bright shades of any colour were more highly preferred than others irrespective of their wave lengths. The female seemed more responsive to colour than the male.

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ON THE DEVELOPMENTAL STAGES OF *MUSCA SORBENS* WIED., WITH SPECIAL REFERENCE TO LARVAL BEHAVIOUR

[*Diptera* : *Muscidae*]

(with 22 Text-Figures and 11 Tables)

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I. INTRODUCTION

As a contribution to our knowledge of *M. sorbens* in Egypt the present authors have given in the first paper of this series (see this Bulletin, pages 83-122) a detailed account on the ecology of the fly, in which such aspects as the breeding media, seasonal prevalence, oviposition, longevity and flight range, etc., were described and discussed. This is another paper which deals with the biology of the developmental stages of the same species with special emphasis on the behaviour of the larva and its reactions to some environmental factors such as temperature, humidity and smell.

Experiments and observations were conducted under laboratory and controlled conditions. In the latter case, seven temperatures (16, 20, 24, 28, 32, 36 and 40°C.) and five humidities (0, 30, 50, 70 and 100% R.H.) were used. In experiments

with the egg two more temperatures (5.5 and 43°C.) and two more relative humidities (85 and 95% R.H.) were also used. The desired relative humidities were obtained from different concentrations of sulphuric acid-water mixtures prepared according to BUXTON (1931), BUXTON and MELLANBY (1934) and SOLOMON (1951). The relative humidities produced by the various acid concentrations were checked before use by means of a tiny hair hygrometer (MELLANBY, 1933).

The results obtained from experiments on the duration of the developmental stages were statistically analysed according to FISHER (1950). Statistical Tables of FISHER and YATES (1948) were used to test the significance of the data obtained.

It seemed useful to use a symbolic formula by which the thermal constant and the developmental zero (the lower threshold of development) were determined, as deduced by BLUNK (1930) in his improved rule of temperature sums. An equilateral hyperbola, e.g. $t = \frac{const}{T - c}$, was found to give these two values, (where it is the duration of development at the temperature T, c = the developmental zero and const = the thermal constant) and the required calculations were far simpler than in other types of formulae such as the catenary (of JANISH and others, 1928-1933) as has been emphasised by BODENHEIMER (1938) and LARSEN and THOMSEN (1940). Such a hyperbola when constructed would also permit the prediction of different durations under various temperature conditions, when the duration of development was known for only 2 points of temperatures as it was also attempted by BODENHEIMER (1925).

It may be added that from the thermal constant and developmental zero a comparison may be made between different species as these two values may vary from one insect to another according to biological and ecological factors.

II. THE EGG STAGE

The egg of *M. sorbens* is pearly white in colour and somewhat cylindrical in shape with a more tapering anterior end. It measures about 1.6 mm. in length and 0.4 mm. in width.

The egg is somewhat curved with a concave dorsal and a convex ventral surfaces. A spindle-shaped area runs along the dorsal surface and is marked on either side by a prominent rib-like thickening. At both ends of this spindle are two bulb-like structures the anterior of which is larger than the posterior.

A flat circular area is differentiated at the anterior end of the egg. This is the micropylar plate (DAVIES, 1950 — in blow-flies). At the centre of this plate is the micropyle.

The surface of the egg shell or the chorion which appears polished shows, on close examination, small areas of different sizes. These include rectagonal, pentagonal, hexagonal and heptagonal areas.

The polygons are filled with granules (better viewed through the blue filter of the microscope) arranged in rows parallel to the sides and in some cases the granulation is quite dense around the periphery.

1. The incubation period

Effect of temperature

Under laboratory conditions the average incubation period lasted 6.25 hours, at 31-34°C. and 100% R.H.

The possible effect of temperature on the incubation period was studied at 5.5, 16, 24, 28, 32, 36, 40 and 43°C., humidity being kept constant at about 100%. Table I summarises the results obtained, from which it is clear that the incubation

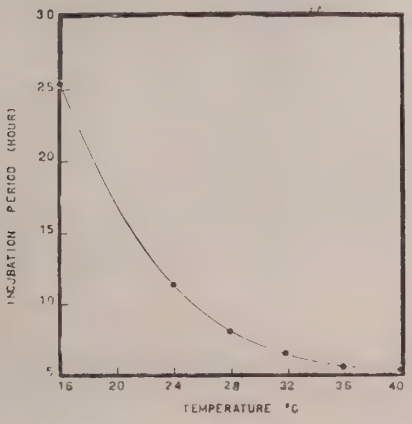

FIG. 1: The effect of temperature on the incubation period of the egg of *M. sorbens*.

period markedly decreased as the temperature increased (Fig. 1). The shortest period (average 5.28 hours) occurred at 40°C. and the longest (average 25.26 hours) at 16°C. At higher temperature (e.g. 43°C.) or lower temperature (e.g. 5.5°C.) eggs failed to hatch.

TABLE I

Effect of temperature on the incubation period of the egg

Temperature in °C.	Number of eggs examined	Incubation period in hours		
		Minimum	Maximum	Mean + s.e.
43	60	—	—	—
40	56	5.00	5.50	5.28 ± 0.02
36	53	5.25	5.75	5.56 ± 0.02
32	66	6.25	7.00	6.53 ± 0.02
28	57	7.75	8.25	7.99 ± 0.02
24	65	11.00	11.50	11.28 ± 0.02
16	57	24.25	26.00	25.26 ± 0.07
5.5	60	—	—	—

Under similar controlled temperature conditions, the eggs of *M. domestica vicina* seem to have a longer incubation period (HAFEZ, 1941; PEFFLY, 1953). Thus at 24, 32 and 40°C., the incubation period in *vicina* was 15.6, 8.6, and 7.8 hours respectively (PEFFLY, 1953) as compared to 11.3, 6.5 and 5.3 hours in *sorbens*.

In the case of *M. domestica*, DAVIDSON (1944) found that the incubation period was 17.16, 9.00 and 8.05 hours at 23.3, 31.7 and 40.0°C. He also found that relatively few eggs hatched at 41.6°C. and none at 42.8°C. Also LARSEN and THOMSEN (1940) stated that at 42°C. all eggs of *M. domestica* died before hatching. These results were in general agreement with those of MELVIN (1934) who stated that the eggs of this species would hatch at temperatures as high as 40.0°C. but none at 42.8°C.

The thermal constant and the developmental zero of *M. sorbens* as deduced from the equilateral hyperbola were 5.97 day degrees and 10.1°C. respectively. These values were obtained by substituting, in the formula, for the duration of development by the values 7.99 and 6.53 hours at 28 and 32°C. respectively. The thermal constant and the developmental zero of *M. domestica* (LARSEN and THOMSEN, 1940) and of *M. domestica vicina* (FELDMAN-MUHSAM, 1944) were 7.5 day degrees and 12.5°C. and 7.4 day degrees and 12.6°C., respectively.

Effect of humidity

The incubation period was also studied at different relative humidities namely 85, 90, 95 and 100%, temperature being kept constant at 31-32°C.

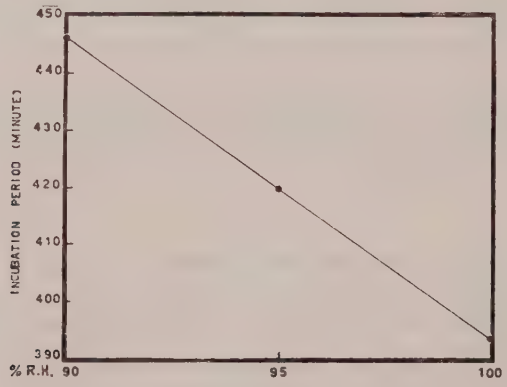

FIG. 2: The effect of humidity on the incubation period of the egg.

From the results obtained (Fig. 2), it was found that the higher the humidity the somewhat shorter was the incubation period. Thus at 100% R.H. all eggs hatched within 6.3-6.6 hours whereas at 95 and 90% R.H. the eggs hatched in about 6.6-7.1 and 7.1-7.6 hours respectively. At 85% R.H. however, all eggs failed to hatch.

Similarly, the eggs of *M. domestica* (LARSEN and THOMSEN, 1940 and LARSEN, 1943) develop optimally at higher relative humidities ranging from 100 to 97%. At lower humidities hatching was retarded 2 to 3 hours and below 91% R.H. at 30°C. no hatching took place.

2. Hatching

When the egg is about to hatch, a dorsal split adjacent to one side of the spindle-shaped area appears. The split usually extends posteriorly and also round the anterior extremity as the young hatching larva crawls out of the egg shell. After the hatching of the larva the egg shell collapses.

Normally the larva crawls out of the egg with its anterior end first, but sometimes however, the larva on hatching may crawl out its caudal end first.

Normal hatching usually occurs at saturation, i.e. at 100% R.H., the larva taking about 30 seconds to withdraw completely from the egg shell. At lower humidities, e.g. 95 and 90% R.H., this period prolonged to 90 and 150 seconds, respectively. In the latter case, the larva often failed to emerge completely, the posterior half of its body remained attached to the egg shell.

Effect of temperature on the number of eggs hatching

The percentages of eggs hatching at different constant temperatures 16, 28, 36 and 40°C. were calculated. The eggs used were fertile and secured from copulated females. This is to obtain the percentage of hatching as affected only by temperature. The results are represented in Figure 3. Maximum hatching, i.e. 100%, occurred at 28°C. Above or below this temperature the percentage of eggs hatched decreased. For example at 16°C. it was 95%, at 36°C. it was 90% and at 40°C. it was 65%.

When comparing the percentages obtained at 36 or 40°C. with those at 16°C. it can be inferred that although high temperatures accelerated development of eggs (Table I) they kill a relatively high percentage of them. On the contrary, at the low temperature 16°C. development was retarded but the percentage of kill was small.

From Figure 3, giving the relation between temperature and the percentage of eggs hatching, it seems that the highest percentages of eggs which hatch are at temperatures ranging from 22 to 28°C.

PEFFLY (1953) did not get consistent egg-hatching percentages for the eggs of *M. domestica vicina* and the maximum hatching (93%) occurred at 75°F. (24°C.) and 95°F. (35°C.). PEFFLY, however, did not mention whether all the eggs he used were fertile or mixed with some sterile ones.

In another experiment groups of eggs taken from the common stock were left to hatch at various temperatures. The percentage of eggs hatching obtained were different (Fig. 3). This difference may be due among other factors to that these eggs may contain some sterile ones which do not hatch, thus biasing the results.

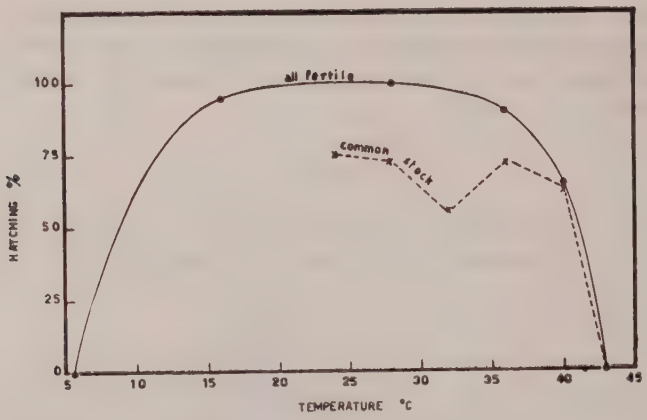

FIG. 3: The effect of temperature on the number of eggs hatching.

The present data when compared with those of PEFFLY (1953) on *vicina* it may be concluded that the percentage of egg-hatching in the case of *sorbens* is lower than in the case of *vicina*, e.g. it is 75 and 55% in the former and 93 and 82% in the latter at 24 and 32°C. respectively.

Effect of humidity on the percentage of eggs hatching

Fig. 4 gives the percentage of eggs hatching as affected by different relative humidities. Maximum hatching, i.e. 96%, occurred at saturation (100% R.H.)

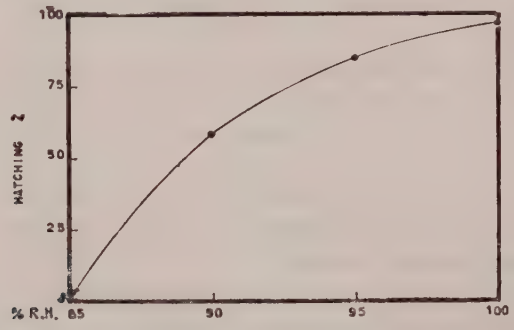

FIG. 4: The effect of humidity on the percentage of eggs hatching.

and the percentage decreased with decreasing relative humidities; thus, it was only 58% at 90% R.H. At 85% R.H. however, no egg-hatching occurred (temperature was 31-32°C.).

In an attempt to explain failure in hatching at low humidities series of experiments on the eggs of *M. sorbens* were conducted to s udy the possible changes in their shape brought about by changes in the relative humidity of the air in their immediate vicinity.

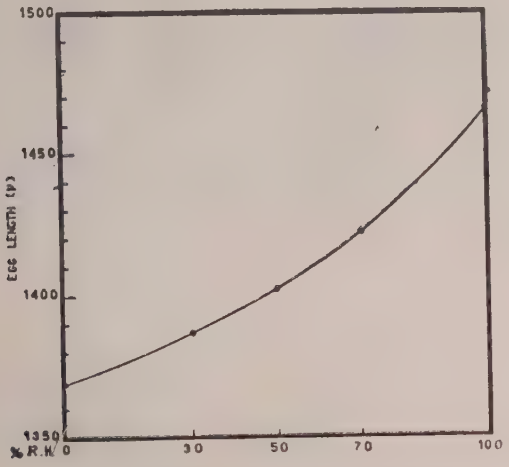

FIG. 5: Variation of egg length with humidity.

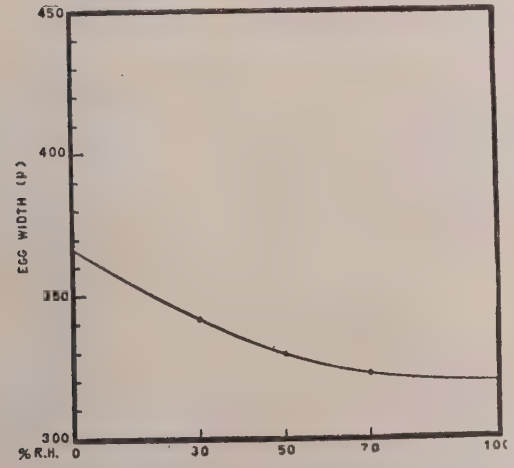

FIG. 6: Variation of egg width with humidity.

Freshly laid eggs were exposed to relative humidities ranging from 0 to 100%. In one series of experiments, observations were recorded every 5 minutes and in another, eggs were exposed for longer periods (about 30 minutes) to obtain maximum effects.

In the first series, when the relative humidity was progressively raised from 0 to 100%, the eggs gradually increased in length whereas a reduction in their cross-sectional area occurred. The variations in the length and width of eggs from 0 to 100% R.H. are shown in Figures 5 and 6.

In an average, the length changes from 1.369 mm. at 0% R.H. to 1.465 mm. at 100% R.H. with an average elongation of 7.0%, whereas the width changes from 0.298 mm. at 100% R.H. to 0.312 mm. at 0% R.H. with an increase of 4.7%. The percentage increase of width at 0% R.H. over the width at 100% was quite marked reaching in some cases 18.1%.

In the second series (with long exposures), the egg increased both in length and width when the relative humidity was raised from 0 to 100%. Table II shows the variation in length and width when the eggs were subjected to 0 and 100% R.H. for long periods.

TABLE II

Variations in egg length and width with long exposures to 0 and 100% R.H.

Dimensions	Extremes at 0 % R.H.	Extremes at 100 % R.H.	Percentage range of variation
Length	1365–1482	1572–1736	13.6–22.3
Width	231–322	389–410	24.2–68.4

In an average, the length changes from 1.393 mm. at 0% to 1.624 mm. at 100% R.H. with an increase of about 16.5%, whereas the width changes from 0.279 mm. at 0% to 0.405 mm. at 100% R.H. with an increase of 45.2%. This may indicate that collapse is a function of width rather than it is of length.

It was further noticed that abrupt humidity changes from 0 to 100% R.H. caused strains in the chorion of the egg. Also, the egg shell was stiffer at lower humidities at which the larvae seemed unable to crawl out from the chorion. Increasing humidities were accompanied by a decrease in the egg volume and consequently the internal pressure increased gradually with increasing humidities.

Similar findings were reported by DAVIES (1950) on *Lucilia* eggs. This author has pointed out that at 100% R.H. the eggs of *Lucilia* (and possibly those of *sorbens* according to the present data), are under maximum strain which becomes less at lower humidities. This is due to the shape changes which at higher humidities result in the increase of the internal pressure of the egg. So, tapping of the larva by its cephalic end on the anterior end of the egg causes quick splitting of the chorion at 100% R.H. while at humidities below saturation the larva must make successive taps to cause rupture. This may result in the failure of the larva to hatch and the chorion may remain unruptured. This also may explain the failure as well as the delay in the hatching of the egg.

Effect of low humidity exposures on hatching

Tests were made to determine the effect of low humidity conditions to which the eggs were subjected for short periods on hatching. Fertile eggs laid within 15 minutes were used for these tests. The eggs were placed on pieces of black drawing paper on the floor of Petri dishes 5 cm. in diameter and were all enclosed in a desiccator of 30% R.H. The experiments were repeated at different time intervals and the eggs after each test were moistened with distilled water and the Petri dishes were covered to establish 100% R.H. The time intervals of 0, 10, 20, 30, 40 and 50 minutes were tested and the experiments were conducted under room temperature (28-30°C.).

It was found that dry a mospheric conditions had a harmful effect on the hatching of eggs, this effect became more pronounced as the time of exposure inc-

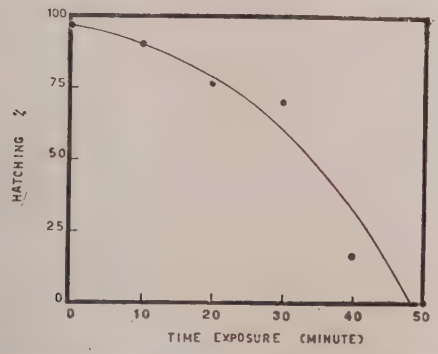

FIG. 7: The effect of short exposures of the egg to 30% R.H. on the percentage of hatching.

reased (Fig. 7); thus 10, 20 and 30 minute exposures produced hatching percentages of 90, 77 and 71 respectively. Further exposure, e.g. 40-minute intervals had a very detrimental effect upon the eggs and most of them (83%) collapsed. After 50-minute exposure, however, all eggs died.

Effect of low humidity exposures on water loss of eggs

Tests were made to examine the rate by which the eggs lost water under room conditions (30% R H., 30°C.). Eggs were exposed to atmospheric air and carried directly on the holder of a torsion balance (sensitivity: 0.1 mlg.). The weights of 50 eggs were recorded in a period of one hour at 10-minute intervals. The results (Fig. 8) showed that water was lost from the egg under such low humidity by about 30% of its weight in 60 minutes. The egg lost about 20% of its weight in the first half-hour whereas it lost only about 10% in the second half-hour. Also the loss in the first 10 minutes (0.6 mlg.) was 6 times as high as that in the last 10 minutes (0.1 mlg.) as the evaporation rate from the egg decreased with increasing time of exposure.

From the foregoing experiments it may be concluded that change of temperature has a marked and significant effect on the duration of the incubation period of *M. sorbens*. At 40°C. the shortest duration occurred while at 16°C. the longest duration was observed. On the other hand, at 43 and 5.5°C. eggs failed completely

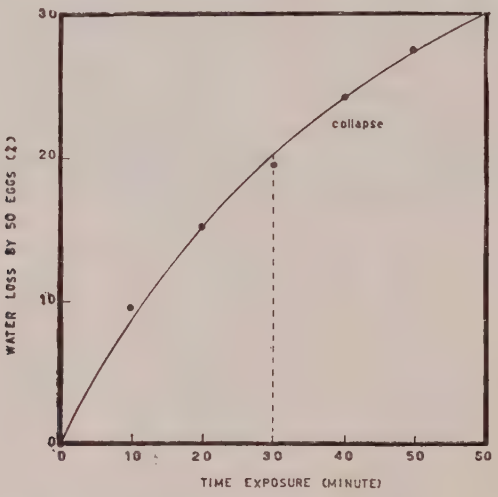

FIG. 8.: Percentage of water loss from 50 eggs in one hour (30% R.H.).

to hatch. However, at 40°C. the percent of egg hatching was relatively small and the maximum percent of egg hatching (100%) occurred at 28°C. (100% R.H.). The percent of egg hatching was higher at the lower temperature 16°C. where egg development was slower than at higher temperatures 36 and 40°C. where egg development was greatly accelerated.

Humidity also plays a significant part in egg development and hatching. Saturation (100% R.H.) was found to be most necessary for these activities where maximum number of eggs hatched (temperature was 31-32°C.). At lower humidities the numbers hatching were considerably reduced and at 85% R.H. the eggs failed to hatch. This was found probably due to shape changes which at higher humidities result in the increase of the internal pressure of the egg, and tapping of the larva caused quick splitting of the chorion; at lower humidities the reverse took place and successive taps had to be made to cause the rupture of the chorion, and this may result in a failure as well as in a delay in the hatching of the larva.

Exposures of the egg to low humidities (30% R.H.) had a harmful effect on hatching. About 30% of the eggs collapsed 30 minutes after exposure and death of all eggs occurred 20 minutes later. The rate of water loss from the egg at this low humidity was twice on the first half-hour (20%) what it was on the second half-hour (10%).

III. THE LARVAL STAGE

1. The larval instars

There are three larval instars. The first instar measures about 1.8 mm. in length with two posterior spiracles each consisting of two slit-like apertures carried on a slight prominence. The second instar is about 3.8 mm. long, and the posterior spiracles are similar to those of the first instar but the slits are larger. The third instar is about 11.2 mm. in length and its posterior spiracles are well developed and show the usual Muscoid structure. Each spiracle has the 3 sinuous slits surrounded by the D-shaped peritreme. The latter is much thicker than that of *domestica* or *vicina*. This is a distinctive character by which the larva is easily differentiated from *M. domestica* or *M. domestica vicina* (JAMES, 1947).

2. The duration of the larval instars

a. *Under room conditions*

Petri dishes 5-cm. in diameter were floored each with four rounded filter papers all saturated with milk to which a small quantity of excrement was added and covered with moistened black paper to furnish a dark background. One larva was kept in each dish and observations on larval growth and durations of the different

TABLE III

The duration of the larval instars at room temperature (mainly 32°C)

Larval instar	Duration in hours	Average duration in hours
First	5 – 8	7
Second	13 – 15	14
Third	38 – 43	40
Total	56 – 66	61

stages were made at room temperature (29-34°C., mainly 32°C.). The durations are given in Table III. The first stage larva hatching from the egg was very small crawling sluggishly in the substratum and feeding actively. It took 5-8 hours to moult into the second larval instar. After moulting or ecdysis, the exuvia appeared as fine translucent filamentous structures on the black floor of the Petri dish.

The second instar which was larger in size and lasted 13-15 hours after which the second ecdysis took place and the third stage larva was formed. At the end of the second stage, the larva moulted to the third larval instar. This latter grew very rapidly and attained a much larger size than any of the previous stages, and was still more active. This stage lasted for 17-20 hours feeding voraciously, then showed a tendency to migrate to cooler and drier regions of its breeding medium and stopped

feeding and moving and remained so for about 21-23 hours during which the larva is said to be in the prepupating stage. Both the feeding and prepupating stages (third larval instar) lasted about 40 hours after which the larva was transformed into the pupa. Thus the total duration of the three larval instars was 56-66 hours, mainly 61 hours (Table III).

Comparing these results with those on the common house fly it seems that *sorbens* has a shorter larval duration. Thus, in the case of *M. domestica* the first, second and third larval instars lasted about 20, 24 and 72 hours respectively (HEWITT, 1914), at 35°C. In *M. domestica vicina* the larval durations were 15, 22 and 46 hours for the first, second and third larval instars respectively at 31°C. (HAFEZ, 1941).

b. *Under controlled conditions*

The larvae were reared on milk-bran mixtures in glass tubes of about 50 cc. in capacity, each filled with about 15 gm. of the larval food and 10 eggs were seeded in each tube. Breeding was conducted in incubators at constant temperatures. The culture tubes being small sized and containing small numbers of individuals and small quantities of larval food, it was expected that the inside and outside temperatures were practically the same.

Towards the end of the larval period the cultures were emptied into thin layers in open Petri dishes and left to dry. Under such drier conditions pupation started, and close observations were made at 6-hour intervals.

The duration period of the larva decreased with increasing temperature. So, at 16°C., the duration was 268.05 ± 0.94 hours, while at 28°C. it was found to be only 90.18 ± 0.73 hours. Further decrease still occurred at higher temperatures, thus at 36°C a minimal duration period was reached after 68.90 ± 0.55 hours. to 73.05 ± 0.71 hours (at 40°C.). A comparison of the larval duration periods at However, too high temperatures seemed to prolong again the duration up different temperatures is given in Table IV and in Figure 9.

TABLE IV

Effect of temperature on the larval duration period

Temperature in °C.	Number of individuals observed	Duration in hours		
		Min.	Max.	Mean ± s.e.
16	57	245	287	268.05 ± 0.94
24	54	90	126	114.00 ± 0.85
28	67	78	108	90.18 ± 0.73
32	57	66	90	74.00 ± 0.57
36	62	60	84	68.90 ± 0.55
40	61	64	94	73.05 ± 0.71

Breeding mixtures with higher milk contents (70% by weight) caused a prolongation of the larval duration, e.g. the latter was completed in an average time of

102 hours instead of 90 hours at 28°C. Under the same conditions the duration lasted for an average period of about 91 and 85 hours at 32 and 36°C. respectively.

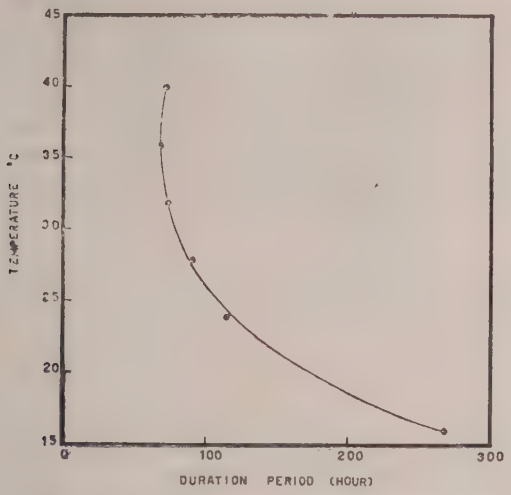

FIG. 9: The larval duration at different temperatures.

When the prepupating larvae were kept in their cultures without providing them with a drier ground suitable for their pupation, the larval duration was prolonged for several days more than the normal one at the same temperatures. For example the average duration period of the larva lasted 25 days (600 hours) at 16°C. and for 8.25 days (198 hours) at 36°C.

It may be interesting to compare the above results with those on *M. domestica*. In the latter, HEWITT (1914) stated that the shortest duration period for the larva was about 5.2 days (124 hours) nearly at 35°C. for the three larval instars. Also KRAMER (1915) found the mean values for the duration of *M. domestica* larva 12.3, 5.1 and 4.3 days at 20,30 and 35°C. DERBENEVA-UKHOVA (1940) stated that the larval development required about 5 days at 43°C., 4 days at 36°C. and 6.5 days at 25°C. In one case of *M. domestica vicina* (HAFEZ, 1941), the duration period of the larvae reached a minimum value of 62 hours at 38°C. FELDMAN-MUHSAM (1944) stated that the duration period of *M. domestica vicina* larva was 14.25 days (342 hours), 6.25 days (150 hours) and 5.1 days (122.4 hours) at 17.5, 29 and 34°C., respectively.

The thermal constant and the developmental zero of *M. sorbens* larvae were found to be 70.3 day degrees and 9.2°C., respectively, by substituting, in the hyperbola, for the duration of development (t) the values 11.4 and 74 hours at 24 and 32°C., respectively. In case of *M. domestica* larva (PEARS, 1927) and *M. domestica vicina* larva (FELDMAN-MUHSAM, 1944), the thermal constant and the developmental

zero were 124.3 day degrees and 5-7°C. (in few cases 8 or 9°C.) for the former and 132 day degrees and 8.0°C. for the latter.

3. Effets of various food ingredients in the larval breeding media on development

The relative effects of certain food materials such as wheat bran, dry yeast, vidamalt and alfalfa meal on the development of larvae of *M. sorbens*, size of the resulting pupae and adults, and on the numbers of adults finally secured, were tested in the laboratory. These food materials form important constituents of several artificial breeding media of various Muscoid flies including *M. sorbens*.

The following combinations of these materials were used, and their proportions were roughly the same as those in the original breeding media : 60 gm. wheat bran, 60 gm. wheat bran mixed with 1 gm. dry yeast, 60 gm. wheat bran mixed with 1.6 gm. vidamalt, 60 gm. wheat bran mixed with 30 gm. alfalfa.

The moisture content of all the above mixtures was nearly the same and was about 60%. Each of these amounts was found sufficient to be divided into six portions, each sustained 50 newly hatched first stage larvae of *M. sorbens*. In choosing this number of larvae care was taken to prevent overcrowding in the medium. Thus, each one of the above mixtures was in fact inoculated with 300 larvae.

The results for each stage were expressed as percentage of the total initial numbers of larvae inoculating the mixture. The sizes of the pupae and adults were determined by weighing the pupae and calculating the average weight of the individual pupa and by measuring the presutural portion of the mesonotum of the adult fly.

Table V gives the results and shows that if wheat bran is used alone, 90% of the initial number of larvae used reach the full grown maggots, 79% successfully pupated while 54% adults were finally secured. This shows that with wheat bran the highest mortality occurred in the pupal stage. When wheat bran was mixed with vidamalt more larvae (95%) reached the mature larval stage than when vidamalt was absent but 64% of which could only pupate indicating that with vidamalt a greater number of larvae died as prepupae. Of the total number of larvae used only 26% reach he adult stage with still high mortality as pupae.

Mixing coarse wheat bran with dry yeast decreased the mortality rate as prepupae and pupae. Most of the larvae inoculating the mixtures, i. e 98%, successfully reached the prepupating stage, 74% pupated and 60% reached the adult stage. This is the highest percentage obtained for all the food combinations tested.

With the wheat bran and alfalfa meal mixtures only 49% reached the full grown larvae, 36% pupated while 8% only reached the adult stage.

As to the sizes of the resulting pupae and adults the fourth and fifth column of the table show that the heaviest pupae (5.0 mlg.) and largest adults (width of mesonotum 1.57 mm.) were obtained from the wheat bran and alfalfa meal mixtures

while the smallest individuals (weight of pupa 3.1 mlg., and width of the mesonotum of adult 1.23 mm.) were obtained from wheat bran and vidamalt mixtures. However, wheat bran and dry yeast also give relatively large pupae (4.3 mlg.) and adults (1.42 mm.).

Thus these results show that yeast seems to be an important constituent of the breeding medium, a relatively large number of well sized flies is produced with an obvious decrease of the percentage mortality in the larval or pupal stages. Alfalfa meal although a more suitable food material producing large individuals, yet a high percentage of these usually die. Furthermore, wheat bran was found to be better if used alone than if mixed with vidamalt.

TABLE V

A comparison between the effects of certain combinations of breeding specialities on the development of M. sorbens

Medium	% individuals produced			Average weight of pupa in mlg.	Average width of mesonotum in mm.
	Larva	Pupa	Adult		
wheat bran	90	79	54	4.0	1.28
wheat bran + vid. ...	95	64	26	3.1	1.23
wheat bran + yeast .	98	74	60	4.3	1.42
wheat bran + alfalfa	49	36	8	5.0	1.57

In another experiment wheat bran was mixed with a sugary solution (20%) to test the direct effect ofsi mple carbohydrates on development. Of the initial numbers of first stage larvae used 95% prepupated, 78% pupated and 53% reached the adult stage. The weight of the individual pupa was 3.5 mlg. while the average width of the presutural portion of the adult mesonotum was 1.27 mm. These figures are almost similar to those obtained by using coarse wheat bran alone (Table V) indicating that sugar is apparently of no significance.

Wheat bran was also mixed with unsweetened milk and with sweetened milk. When these mixtures were offered to the larvae the most striking results were the large sized pupae obtained from both food mixtures. However, the individuals reared from wheat bran and unsweetened milk were larger than those obtained from the other mixture. The average pupal weight reared from the first mixture was 11.8 mlg. compared with 8.6 mlg. from the second. The number of mature larvae, pupae and adults obtained from both foods were : unsweetened milk gave 82% full grown larvae, 87% pupae and 64% adults; sweetened milk produced 94% larvae, 88% pupae and 71% adults. The slight difference between the two mixtures may also emphasize the almost non significance of sugar.

In nature, the highly favoured larval food is human excrement which consists of several substances including 65-80% water and one third of the dry matter is represented by bacteria, 5-10% nitrogen, 10-20% fat and 10-20% ash (THORPE, 1949). As to the relative importance of these constituents in the food of the larvae

relatively little is known, yet many workers have emphasized the nutritive role of microorganisms, bacteria, etc. BOGDANOW (1906, 1908), working particularly on the flesh fly *Calliphora vomitoria* and making also some observations on the house fly *Musca domestica*, found that sterile larvae on sterile food never developed normally. He concluded that the immature forms require for maturation a definite, rather simple bacterial flora. WOLLMAN (1922) pointed out that the micro-organisms might themselves serve as food material. GLASER (1924) stated that bacteria and yeast were essential accessory growth elements for the proper development of the larvae of *M. domestica*. BODENHEIMER (1931) stated that certain fermentive processes which attract the ovipositing females of *M. domestica*, also contributed to providing food for the larvae.

4. Larval habits and habitat

In nature, human excrement is the most favoured breeding medium for the larvae of *M. sorbens*. On rare occasions, however, they are found in pig dung or fresh fuel cakes (buffalo dung). The larva prefers the semifluid medium in which it tunnels actively avoiding direct light.

Larvae reared on human excrement are healthier than those reared on buffalo or pig dung and generally give rise to larger sized flies. This was demonstrated in series of breeding experiments in which equal quantities (40 grams) of human excrement and buffalo dung were used as rearing media for young larvae (50 per test). The results are given in Table VI. It was found that a high percentage, i.e. 74%, of the larvae bred from human excrement gave rise to adults compared to 47% only from buffalo dung.

There was also a marked difference in the size of the resulting pupae and adults reared from both materials. The largest adults and heaviest pupae were produced from human excrement. Another significant effect was the acceleration in development of the flies reared from human excrement compared with buffalo dung.

TABLE VI

The development of M. sorbens *from human excrement and buffalo dung*

Medium	% individuals produced			Average weight of pupa in mlg.	Average width of mesonotum in mm.	Days to emergence
	Larva	Pupa	Adult			
Human excrement .	76	76	74	14.2	1.98	8.8
Buffalo dung	90	80	47	5.0	1.50	9.2

This high suitability of human excrement for development might have a bearing on the great attraction offered by this medium to the flies of *M. sorbens* in nature.

The resistance of larvae to food deficiency depends on the stage of the larvae and on the surrounding conditions. For instance, a newly hatched larva in a moist

environment can withstand starvation about 10.2 hours and is able to moult to the second instar whereby it perishes if not provided with food. In dry atmosphere, however, the larvae were not able to withstand starvation except for few minutes.

On the other hand, a full grown maggot if starved usually changes its colour into creamy white and soon pupates on the next day. The pupae obtained from such larvae, however, are small and give rise to undersized flies.

When about to prepupate the full grown maggot stops feeding and search for a dark dry cool place to pupate. It may even penetrate the soil, hard or loose, for this purpose. The power of penetration of the prepupating larva was demonstrated experimentally by tying a small metal plate with a thin wire to the larva. Weights were then added to the metal plate and the larva was left free to move and pull these weights. The average weight pulled by a larva 14.8 mlg. was found to be 15.2 gm., which is about 1000 times heavier than its own body weight. This result may explain the high power of penetration of the prepupating larvae to fairly hard or loose soil, for pupation.

The larvae of *M. sorbens* is resistant to low temperatures and can withstand 0°C. for a period of six hours, without any apparent ill effect due to such an exposure. Feldman-Muhsam (1944) stated that 100% of the larvae of *M. domestica vicina* can withstand a temperature of — 4°C. for twenty-four hours. Bodenheimer (1931) places the critical cold temperature for the larvae of *M. domestica* at 5°C., but Petrischeva (1932) found that mature larvae of the same species might survive 14 days at temperatures ranging from —1 to —2°C.

IV. THE LARVAL BEHAVIOUR

For a better understanding of the ecology of *M. sorbens* and the behaviour of the larva in its natural environment, series of experiments were undertaken in the laboratory in which the reactions of the larva, at both the feeding and prepupating stages, to such environmental factors as humidity, temperature and smell were studied. The results obtained were compared with those on the house fly larva, *M. domestica* (Hafez, 1950-53).

1. Reactions to humidity

Reactions to air humidity have been experimentally studied in a number of insects, e.g. *Locusta* (Kennedy, 1937), *Blatta* (Gunn and Cosway, 1938), *Culex* (Thomson, 1938), *Tenebrio* (Pielou and Gunn, 1940), *Pediculus* (Wigglesworth, 1941), wireworms (Lees, 1943), *Ptinus* (Bentley, 1944), *Musca* larvae, feeding and prepupating stages (Hafez, 1950-53), *Tribolium* (Willis and Roth, 1950), certain Carabid beetles (Perttunen, 1951) and *Aedes aegypti* and *Blatella germanica* (Roth and Willis, 1952.).

The apparatus and methods used for demonstrating the humidity reactions of the larva were substantially the same as those described by HAFEZ (1950-53). The apparatus was an alternative chamber consisting of a Petri dish 9 cm. in diameter and 1 cm. deep which was divided into two equal compartments by a median double glass partition embedded in wax. A circular glass ring of equal dimensions as the Petri dish and with a fully stretched bolting silk floor rested over the Petri dish. The ring was roofed by a glass plate (11 cm. in diameter) with two small holes, one on each side, through which the humidity was calibrated by a hair hygrometer and the experimental larvae were introduced. A glass septum 5 mm. in depth, embedded in wax, was fastened across the roof to minimise the area of contact between the air on each side. Sulphuric acid-water mixtures were used for controlling humidity (BUXTON, 1931; and BUXTON and MELLANBY, 1934). Before the experiment, the desired concentrations of the acid were placed in the compartments, the glass roof was rendered air tight with vaseline and the two holes were covered with small pieces of vaselined glass. The apparatus was then left about half an hour for the humidity equilibrium to become established (HAFEZ, 1950). After checking the humidities by hair hygrometers, the larvae were introduced through one of the holes in the roof of the arena. The entire apparatus was covered by a larger Petri dish 12 cm. in order to isolate the arena from the outside atmosphere. Uniform light (25 foot candles) and temperature conditions (28°C.) prevailed throughout the experiment.

A single fresh larva was used for each experiment, and 10 experiments were carried out to test the reaction of the larva to a given pair of alternative humidities. Half way through these experiments, the two sides of the arena were interchanged (by rotating the alternative chamber 180 degrees) in order to eliminate any possible bias of the larva towards one particular side. Each experiment lasted for 10 minutes.

The tracks made by the larva on the floor of the arena were copied on a sheet of paper alongside the apparatus, and one minute intervals were marked on the tracks. By this means the time spent by the larva on the two sides of the arena was recorded. The intensity of the reaction was expressed when required as the excess percentage $100\ (\frac{W-D}{W+D})$ (GUNN and COSWAY, 1938), where W and D were the time spent by the larva on the wetter and drier sides respectively, the time spent by the insect in the middle zone was ignored.

The larvae used in these experiments were obtained from a standard culture (reared on milk-bran mixture). The experimental larvae were of nearly the same age and size (feeding larvae: 36 hours; prepupating larvae: 72 hours).

Experiments and results

Extreme alternatives

The reaction of the larva towards wet and dry surfaces was tested. The glass ring rested on a sheet of blotting-paper devided into 2 equal halves; one saturated with water and the other left dry. The arena was left open above and the larval

tracks were observed. In all cases the insects persistently avoided the dry side (Fig. 10A). The same reaction was obtained when the larva had to choose between dry air and saturated air produced by concentrated sulphuric acid and water respectively. The reverse took place with prepupating larvae, which always avoided the wet side (Fig. 10 B). See also Figures 11 A and B.

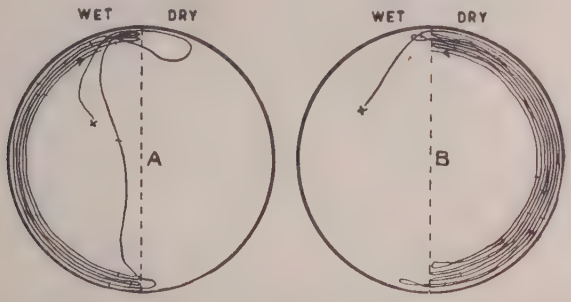

FIG. 10: Reactions of the larva to dry and wet surfaces (A, feeding stage; B, prepupating stage).

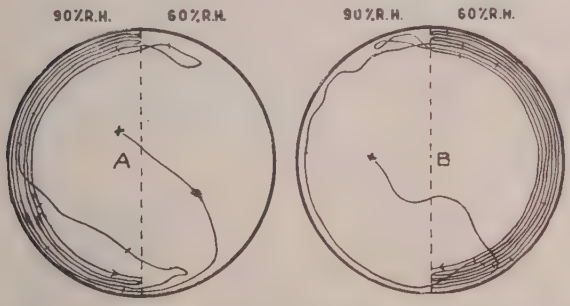

FIG. 11: Reactions of the larva to moist and dry air in the alternative chamber (A, feeding stage; B, prepupating stage).

Uniform humidities

The behaviour of the larva at uniform humidities was tested in a series of control experiments. The relative humidities used were 30, 60 or 90% each in a single treatment. At 90% R.H. the larva walked straight around the wall of the arena at an average rate of 9.5 cm./min., while at 30% R.H., it moved erratically at a higher rate (15.5 cm./min.). An intermediate behaviour was obtained at 60% R.H. Prepupating larvae, on the other hand, followed a convoluted course at low and high humidities (30 and 90%), but walked in straight lines at 60% R.H. Moreover, the movements of the larva were quicker at 30 and 90% R.H. than at 60% R.H.

Alternative humidities

When the larva was given a choice of relative humidities of 90 and 100% a marked reaction became obvious, the larva persistently avoided the drier side and turned back to the moister side on reaching the humidity boundary (Fig. 12 A). The intensity of reaction expressed as excess percentage on the moist side was thus

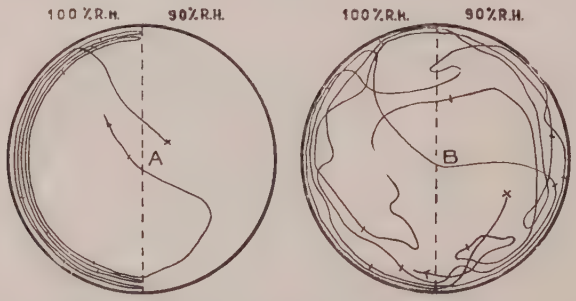

FIG 12: Reactions of the larva to humidity within the range 90-100% R.H. (A, feeding stage; B, prepupating stage).

about 100%. The following pairs of alternative humidities were also used : 100 or 90%, 90 or 80%, 90 or 70%, 80 or 70%, 80 or 60 %, 70 or 60%, 70 or 50%, 60 or 50%, 50 or 40%, 50 or 30%, 50 or 20%, 40 or 20%, 40 or 10%, 30 or 20%.

The larva was indifferent to differences as great as 30% R.H. below 40% R.H. For example no preference was shown by the larva when offered alternatives of 40 or 30, 40 or 20 and 40 or 10% R.H.

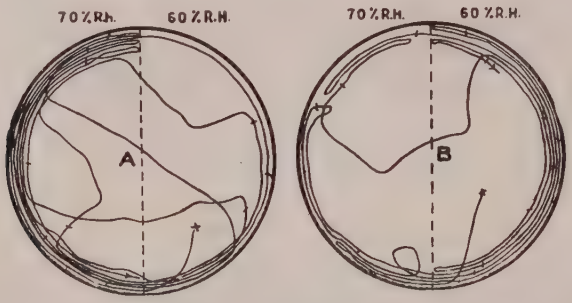

FIG. 13: Reactions of the larva to humidity within the range 60-70% R.H. (A, feeding stage; B, prepupating stage).

Above 40% R.H. the larva spent more time on the moister side than on the drier (Fig. 13A), however, when the larvae were offered an alternative of 50-40% R.H. no reaction seemed to occur. The reaction intensity also varied with varying

the humidity range, e.g. the reaction intensities at 70-80, 80-90 and 90-100% R.H. were 70, 83 and 95% respectively. It was assumed then, that the higher was the humidity range, the greater was the intensity of reaction. HAFEZ (1950), working with *domestica* larva, stated that in the presence of 100% R.H. all lower humidities were avoided, e.g. small humidity differences such as 2% at 95 to 100% R.H. was sufficient to produce clear avoidance of the drier side. This sensitivity of the larva to humidity was greatest when the alternative offered was close to saturation. The same phenomenon was observed in *Tenebrio* (PIELOU and GUNN, 1940), in *Culex* (THOMSON, 1938), in *Pediculus* (WIGGLESWORTH, 1941) which are all more sensitive to humidity within the higher humidity range.

In the prepupating stage it was found that the larva preferred a medium relative humidity to a low or a high humidity. Above 80% R.H. the larva was unaffected by a difference of 10% (100 or 90% and 90 or 80% (Fig. 12 B). However, when offered an alternative of 80 or 100% R.H. the insect showed a marked avoidance of the higher humidity. It was found also that in the presence of 60% R.H. on one side of the arena all higher humidities were avoided (Fig. 13 B) and the intensity of the reaction depended on the humidity differences of the alternatives offered,

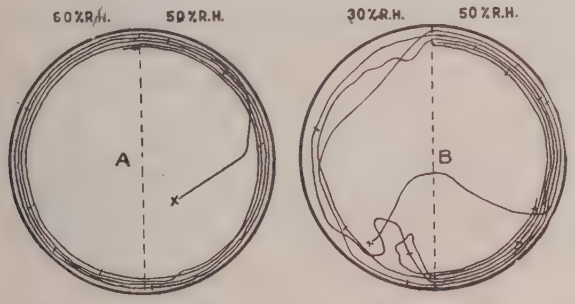

FIG. 14: Reactions of the prepupating larva when offered the alternatives (A) 50-60% R.H., and (B) 50-30% R.H.

e.g. at a difference of 10% (70 or 80% R.H.) and 20% (60 or 80% R.H.) the reaction intensities were 27 and 52% respectively. The larva was indifferent to the humidity difference when offered the alternative 50 or 60% R.H. (Fig. 14 A). The larva was also indifferent at 50 or 40; 40 or 20; and 40 or 10% R.H. At 50 or 30 (or lower), the drier side was avoided (Fig. 14 B).

The apparent low sensitivity to humidity at the lower humidity range may be due to, as LEES (1943) has pointed out, to failure in the operation of orientation mechanism rather than to real indifference to humidity.

Pre-conditioning

The larvae were kept at 30 or 60% R.H. for 5 hours and then offered an alternative in which one side of the humidity chamber was kept constant at 90%

R.H. The lower humidity of the other side in the alternative was the same as that at which the larva had been previously kept. No marked effect due to preconditioning was observed, and the larva showed a consistent avoidance of the drier side. The same was also observed with prepupating larvae, preconditioning had no effect upon the behaviour of the larva, the latter consistently avoided the moister side.

Mechanism of orientation

The larva when crossed the wet side to the dry, the rate of movement increased, till the larva returned to the moist zone. This is an example of orthokinesis involving a change in linear velocity of the larva. On the other hand, the larva when entered the dry zone no longer moved in straight lines along the periphery of the arena but instantly changed its course in an agitated manner till it regained the wet side. This is a klinokinetic reaction manifesting a change in angular velocity. At higher humidity ranges a directed reaction or taxis became obvious, the larva persistently recoiling back to the moister side on reaching the middle zone of the arena. This mechanism of orientation was reported by HAFEZ (1950) working on *M. domestica* and described as a klinotactic reaction involving a comparison of two intensities of stimulation in successive intervals of time.

It seems, therefore, that there are 3 types of orientation mechanisms namely the orthokinesis, klinokinesis and klinotaxis, by which the larva consistently avoids the lower humidity and passes over again into the more favourable zone of higher humidity. However, there is no distinction in kind between klinokinesis and klinotaxis (HAFEZ, 1950). In its extreme form, produced merely a change in the stimulation pattern, klinokinesis becomes klinotaxis. The same mechanisms seem also to contribute to the general humidity behaviour of the prepupating larva in the alternative chamber.

2. Reactions to temperature

The apparatus used for studying the temperature reactions was similar to that devised by WIGGLESWORTH (1941). Hot and cold water circulated in two copper tanks 20 × 20 × 9 cm. in diameter. The two tanks were separated by a sheet of asbestos about 2 mm. thick, and held together by a copper strip. The temperature was adjusted by micro-burners or ice for the warm and cold sides, respectively. From each tank a thermometer projected out, the bulb of which inserted very close to the surface (internally) on which the arena was enclosed by a glass ring 9 cm. in diameter. Half of the arena rested on one tank, and half on the other. the experiments were made either in dry air at about 50% R.H., or in moist air at about 100% R.H. with water in direct contact with the larvae under test. In the latter case a moistened floor was made by blotting-papers saturated with water. The glass ring was roofed by a glass plate, and the whole arena was enclosed by an inverted Petri dish. The light was controlled in the same way used in the humidity experiments. The apparatus was rendered air tight and when set up a larva was introduced, through one of the holes in the glass roof. The reaction of the larva to temperature was then studied.

Experiments and results

Extreme alternatives

The larvae were first given a choice of 25 or 40°C. They strongly avoided the high temperature. When given an alternative of 25 or 10°C. the larvae preferred the warm side, and showed an avoidance of the cool zone but not so strongly as in the case of higher temperatures (Figs. 15 A and B).

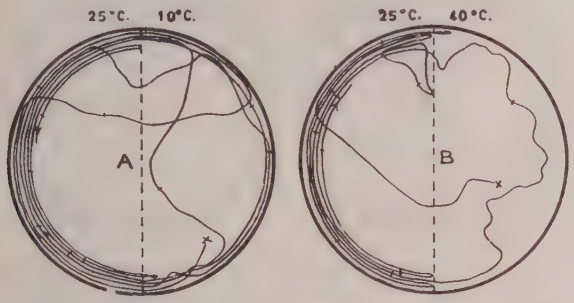

FIG. 15: Tracks followed by feeding stage larvae showing reactions to (A) low, and (B) high temperatures.

Uniform temperatures

Uniform temperatures at 10, 15, 20, 25, 30, 35 and 40°C. were established and the larval tracks were found to be convoluted at high (35 and 40°C.) and at low (10°C.) temperatures but straight and regular at moderate temperatures (25°C.). Also the rate of movement increased with increasing temperatures.

Alternative temperatures

The temperature was kept on one side at 25°C. and progressively raised or lowered on the other side. Below 25°C. the larva was indifferent to a temperature difference of 8-9°C., e.g. no choice was observed when an alternative of 25 or 18°C was used, but when the temperature on the cooler side was lowered to 16°C. the larva began to show but a slight avoidance of the lower temperature (Fig. 16 A). However, the reaction was strong at 25 or 10°C. on the cool side the larva was often seen to turn aside and to follow a more or less convoluted course until it returned to the warm zone.

The larva was again indifferent to 3-4 degrees above 25°C., so no definite reaction was obtained at 25-28°C. or 25-29°C. A slight avoidance of the high temperature could be observed at 25 or 30°C. (Fig. 16 B). The higher temperature was sharply avoided at 25 or 31°C, and was still more at 25 or 33°C. Above 30°C. the larva reacted to a difference of 1°C., and spent nearly all its time on the cooler zone. For instance, when the alternatives 30 or 31°C. and 32 or 33°C. were used the larva

persistently avoided the higher temperatures. In contrast with this sensitivity to 1°C. difference at temperatures above 30°C., there was no response to the same difference at temperatures below 16°C., e.g. at 15 or 16°C. and 14 or 13°C. A wide temperature range extending from 16 to 29°C. occurred in which the larva was indifferent to about 9°C. difference, e.g. 18 or 27°C.

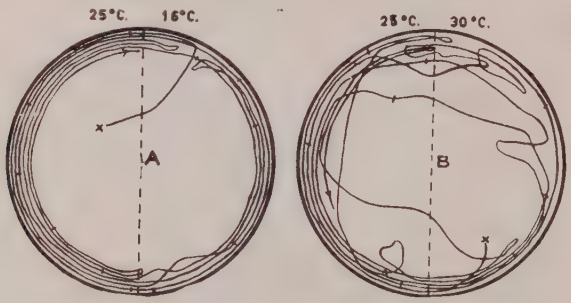

FIG. 16: Tracks followed by feeding stage larvae showing first avoiding reactions to (A) low, and (B) high temperatures.

When the above experiments were repeated at about 100% and with a moistened floor (a condition similar to that in which the larva is always found in nature), the insect was indifferent to greater temperature differences, e.g. at 25 or 39°C. and 25 or 40°C. Very slight avoidance of the higher temperature began when an alternative of 25 or 41°C. was offered, and the avoidance became more obvious at 25 or 43°C. At the lower temperature range the larva was indifferent to either side of the arena when the alternative offered was 16 or 25°C. At 15 or 25°C., the first avoiding reaction toward the cooler side was obtained.

It was concluded, therefore, that the larvae preferred a lower temperature in dry air than in moist, and that the indifference range was wider (25-40°C.) in the moist air with water in contact than in dry air (25-30°C.). Similar results were obtained by HAFEZ (1950) on *domestica* larvae, the zone of indifference was 25 - 31°C. at 50% R.H., 25-33°C. at about 100% R.H. and 25-39°C. at saturation with moist surface. At the lower temperature range (below 25°C.), the zone of indifference was practically the same as that of *sorbens* ranging between about 15 and 25°C.

When the temperature reactions of prepupating larvae were studied, the temperature was kept in most cases constant at 20°C. on one side of the alternative chamber, but lowered or raised on the other. Below 20°C. the larva was indifferent to a difference of 3°C., e.g. when offered a choice of 20 or 17°C, a weak avoidance began to appear using the alternative of 20 or 16°C., the larva avoided the cooler side (Fig. 17 A). Also, when the temperature was raised above 20°C. the larva was again indifferent to 4°C., when offered a choice of 20 or 24°C., but at an alternative of 20 or 25°C. the cooler side was preferred (Fig. 17 B). However, a weak avoiding

reaction of the higher temperature was clearly demonstrated to a difference of 1°C. at 25 or 26°C., and stronger avoiding reaction of the warmer side was observed at 26 or 30°C. On the other hand, the larva was indifferent to temperature differences

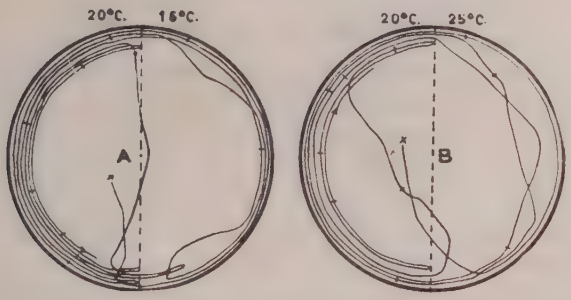

FIG. 17: Tracks followed by prepupating larvae showing first avoiding reactions to (A) low, and (B) high temperatures.

of 5 or 6°C. at the lower temperature ranges (15 or 9°C., 15 or 10°C.). A slight avoidance of the lower temperature was observed at 16 or 9°C. and 15 or 8°C. As to the indifference temperature zone a range extending from 16 to 25°C. in which the larva was not sensitive to 7°C. difference, did exist. It was noticed also that the larva was more sensitive to temperature at higher than at lower temperature ranges.

Similar results were obtained by HAFEZ (1953) on *domestica* larva and found that the prepupating stage preferred cooler temperatures than the feeding stage. However, the indifference zone of the larva was 8-20°C. THOMSEN and THOMSEN (1937), working with the same species mentioned that the prepupating larvae, preferred temperatures below 15°C.

Pre-conditioning

Larvae were preconditioned either at 35°C. or at 10°C., and their reactions to temperature were then examined at alternatives of 25 or 35°C. and 25 or 10°C. In both cases the larvae showed preferrence to 25°C. Preconditioning again seemed to have no effect on the behaviour of the larva to temperature. The same finding was obtained with prepupating larvae.

Mechanism of orientation

Orthokinesis, klinokinesis and klinotaxis are again the mechanisms which are involved in the temperature reactions of the larva. Orthokinesis was observed at uniform as well as at alternative temperatures. Klinokinesis came into action as the larva crossed to the unfavourable side of the arena. Klinotactic reaction was well demonstrated at steep temperature gradients. This mechanism is certainly very

effective in keeping the larva away from the adverse zone, the other two mechanisms, however, are important factors in the oierntation of the larva to temperature. At low temperatures, klinokinesis is mostly the mechanism involved. The same mechanisms were recorded in action in prepupating larvae.

3. Reactions to smell

For the smell experiments the apparatus was the same as that used for studying the humidity ractions, but the arena was left open. Light was adjusted at 5 foot-candles and the relative humidity throughout the experiments was near saturation. Under such conditions the odours of the appropriate solutions in both sides of the lower Petri dish could be carried upwards on the surface of the voile by convection currents, and form in still air a steep gradient in the middle line between the two halves as assumed by WIGGLESWORTH (1941). Certain odours of some particular substances, that were expected to be encountered in the natural habitat of the larva, were tried. Ammonia, acetone, acetic acid, formic acid, alcohol, skatole, indole, human excrement and milk were used in water. The concentrations prepared were as follows : ammonia or acetic acid in 0.5% solution, alcohol or acetone in 1% solution, formic acid in 1 or 2% solution, skatole or indole (few crystals thoroughly shaked in water then filtered), milk (diluted) on which the larva was previously reared, then human excrement diluted and left to settle (water contaminated us d)

Experiments and results

When one side of the arena contained ammonia, alcohol, acetone, skatole or indole and the other side was untreated, the larva always favoured the scented

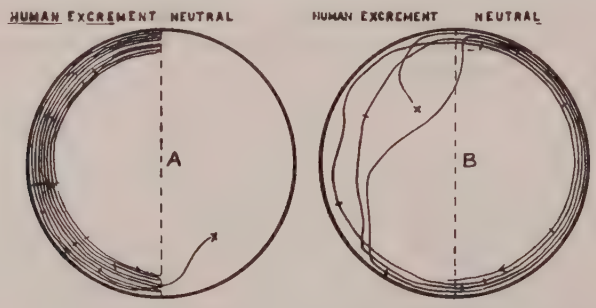

FIG. 18: Reactions of the larvae to human excrement (A, feeding stage; B. prepupating stage).

side. On the other hand, the reverse occurred when formic or acetic acids were used, milk or excrement the larva strongly preferred the scented side and avoided the larvae followed a more or less convoluted course on the scented side. Using neutral one. See Figures 18 A, 19 A and 20 A.

When the larva was offered the choice of acetone or ammonia, it was indifferent to either side (Fig. 21). By using skatole or indole as alternatives the insect showed slight preference to indole. The larva also strongly preferred the odour of human

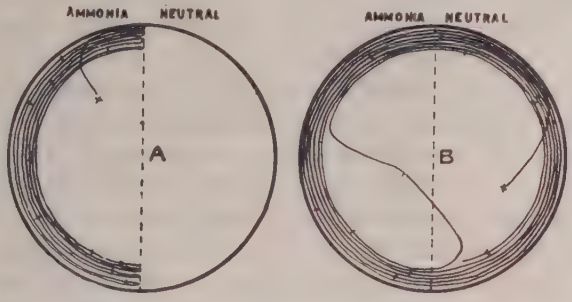

FIG. 19: Reactions of the larvae to ammonia (A, feeding stage; B, prepupating stage).

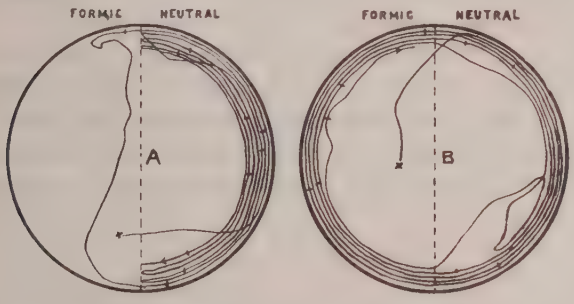

FIG. 20: Reactions of the larvae to the smell of formic acid (A, feeding stage; B, prepupating stage).

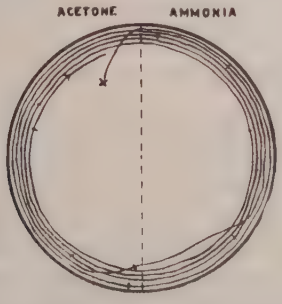

FIG. 21: Reactions of feeding stage larvae to the smell of ammonia and acetone.

excrement to that of milk. When the alternatives ammonia or acetic acid and ammonia or formic acid were offered the larva preferred ammonia scented side, and strongly avoided the acid scented side.

HAFEZ (1950), working with *M. domestica*, similarly found that the larvae preferred zones of ammonia or acetone and avoided the acid scented side of acetic, formic, propionic or butyric acids. He further tested the response of the larva to the odours of pig and horse dung and milk; the larva preferred the first to the second and the latter to the third. However, they were all preferred when the other side of the alternative chamber was neutral.

Experimenting with prepupating larvae a weak avoiding reaction of the scented side was observed when milk, human excrement, indole, skatole or alcohol occurred at one side of the arena, and the other was left neutral. When one side had acid and the other was untreated, the larvae slightly avoided the acid-smelling side, but some were completely indifferent to the smell even when the concentrated solution of acetic (1%) or formic (2%) acid was used (Fig. 20B). In an arena with ammonia or acetone on one side, the insect showed no preference to the smells emanating from these two compounds. However, when the larva was offered the choice of ammonia or acetic acid a preference was observed to the ammonia scented side. See Figures 18 B, 19 B and 20 B.

Judging by some of these results it seems that the olfactory sense of the prepupating larva has been diminished as compared with that of the feeding larva. This was demonstrated by the weak avoiding reaction of the larva to the repellent smell of acetic acid or its complete disappearance. A similar change in the olfactory behaviour of *M. domestica* larva at the prepupating stage was reported by HAFEZ (1953).

Mechanism of orientation

Klinokinesis was observed when the larva crossed the favourable scented side to the adverse zone. The larva followed an irregular course on the unfavourable half and returned back to the preferred one. A directed reaction "taxis" was also marked out when the larva was subjected to a very repellent smell in one side of the alternative chamber. This was a klinotactic reaction. The two mechanisms were found to operate in prepupating larvae as well.

The reactions of the larva and the natural environment

The foregoing experimental study of the behaviour of the larva may shed some light on its life in the normal environment. Larvae of *M. sorbens* are found most commonly in isolated human stools. Inside such deposits the temperature does not vary considerably from that of the surrounding atmosphere. For instance when the temperature of positive stools was 16-16.5°C. that of the surrounding atmosphere was 17.5-18°C. Prior to pupation the migration of the larva does not seem to be induced by temperature. This can be seen from the slight difference between the preferred temperature range of the feeding larva (16-29°C.) and that of the prepupating larva (16-25°C.), which both coincide in their lower limits (16°C). The latter range is likely to occur beneath the stool on the soil surface or deep in the soil where

pupae are commonly found. The *M. domestica* larvae on the other hand, breeding principally in horse manure heaps occur in the upper layers where the temperature ranges between 30 and 40°C., and prior to pupation these migrate to cooler sites in the edge of the dung heap or the surrounding earth where the temperature is from 20-25°C. (THOMSEN and THOMSEN, 1937). The thermo-preferendum of the pre-pupating larva of *domestica* lies within the range 8-20°C. which is much lower than that of the feeding larva 15-33°C. (HAFEZ, 1953).

Therefore, it may be concluded that factors other than temperature are likely to be concerned with the migration of prepupating larvae from inside the stool to the regions below on the soil surface.

The pre-pupating larvae prefer a relative humidity range of 50-60%, and strongly avoid higher humidities. This is typical of the larval behaviour in its normal environment; prior to pupation the larva leaves the moist inside of the stool and seeks drier sites underneath. On the contrary, the feeding larvae favour humidities near saturation above all other lower ones which is also typical of the microclimate of the larva. The avoidance of low humidities by the feeding larva may be a safe guard against the danger of the desiccation of the stools.

The marked preference of the feeding larva for the smell of human excrement is in agreement with field observations and experiments. The preference for ammonia is again not surprising as this substance occurs in the natural breeding medium of the larva. The avoidance of human excrement, the natural breeding medium of the larva may lead to conclude that the larvae, prior to pupation probably seek not only drier but also less odoriferous sites underneath the stool in the soil.

The operation of the orientation mechanisms previously demonstrated can be visualized in the natural environment of the larva. The distribution of the larvae in the breeding medium within the zone of preference and their migration, prior to pupation, to drier and probably to less odoriferous sites, may be due to klinotactic, klinokinetic and possibly orthokinetic reactions.

V. THE PUPAL STAGE

1. Pupation

Prior to pupation, the larva stops feeding and turns creamy white in colour, and becomes very sluggish and finally contracts. The anterior end (pseudocephalon) is withdrawn and a more or less barrel-shaped puparium is formed (apparently 12 segmented). The colour which is at first creamy white gradually darkens and finally turns dark brown within about 3 hours. The anterior spiracles appear as minute tubercles, while the posterior spiracles are seen as 2 flat button-like structures on the hindmost extremity of the pupal case. The ventral surface of the pupa is marked by the spiniferous cushions of the abdominal segments used by the transform-

ed larva for locomotion. Later on, two small spiracles, the pupal spiracles, are formed on the dorsal side between the first and second abdominal segments.

Musca sorbens puparia formed by the transformation of healthy larvae attain a dark brown colour of the chest nut type, measuring about 5.9 mm. in average length and 2.4 mm. in average width. On the other hand, puparia of *Musca vicina* can easily be distinguished from those of *Musca sorbens* by their characteristic mahogany-brown (purple brown) colouration. The average length of *vicina* puparia is about 7.0 mm. (HAFEZ, 1941); whereas in *domestica* it is 6.3 mm. according to HEWITT (1914).

Normally, well fed larvae produce healthy pupae of normal size. However, when larval breeding media other than human excrement or milk-bran mixtures were used the resulting puparia were usually undersized. Also, the lack of proper moisture content or milk content in the medium of the larva brought about the same result. In addition, it was further noticed that larvae pupating in media with high moisture contents either failed to pupate or produced light coloured puparia. Under such unfavourable conditions for pupation the pigmentation of the pupal case was never completed and the colour shades varied from pale-yellow to pale brown.

Abnormal pupation was also observed in which the larva did not complete its contraction but pigmentation took place throughout the body. In such cases puparia were larva-shaped. In other instances, the contraction occurred at the anterior end of the larva only and this underwent pigmentation while the posterior continued to be pale-yellow and was not contracted. No emergence was recorded from such abnormal puparia. The same observations were reported from *vicina* (FELDMAN-MUHSAM, 1944).

Pupation at different levels

The tendency of the larvae to pupate at different levels of the soil was tested in the laboratory. Ninety prepupating larvae were released over or at the bottom of 10 or a 16 cm. sand column in a graduated cylindrical glass jar. The migration of the larvae inside the column to varying depths was followed and the pupae at each level were counted few days later. During the experiment the jars were kept in a dark place. Each experiment was repeated 6 times.

1. — *The migration of the larva to higher levels* : In these experiments the prepupating larvae were released at the bottom of 16 cm. sand columns and their distribution was observed few days later.

The larva showed preference for pupation at lower depths; and about 40% of the pupae or more were found in the deepest layers of the sand, apparently pupated where they were released. Other pupae, however, were observed few centimetres below the surface (Table VII).

As to the distribution of the pupae within the sand column it was found that about 18% of the larvae pupated in the upper zone (1-6 cm. deep), about 19% in the middle (6-11 cm. deep) and about 63% at lower levels (11-16 cm. deep).

TABLE VII

The migration of the larva to higher levels for pupation

Depth in cm.	Number of pupae encountered at each depth	Depth in cm.	Number of pupae encountered at each depth
1	0	9	3
2	5	10	0
3	5	11	2
4	6	12	0
5	0	13	11
6	0	14	4
7	12	15	6
8	0	16	36

2. — *The migration of the larva to lower levels :* Sand columns 10 cm. deep were used and the prepupating larvae were released over the superficial layer of the sand in the glass jar. Few days later the distribution of the pupae was recorded at different depths. The results are summarised in Table VIII. The majority of pupae

TABLE VIII

The migration of the larva to lower levels for pupation

Depth in cm.	Number of pupae encountered at each depth	Depth in cm.	Number of pupae encountered at each depth
1	42	6	10
2	16	7	4
3	3	8	3
4	6	9	0
5	4	10	2

(about 62%) were found in the upper sand layers (1-3 cm. deep) whereas 22% of the pupae were found in the middle (4-6 cm. deep) and 10% at the lower levels (7-10 cm. deep).

HUTCHISON (1914) found that the behaviour of the pre-pupating larvae of *M. domestica* was greatly affected by the presence or absence of moisture. Of these 98-99% left the manure if the latter was kept moist, and only 70% migrated when the manure was more or less dry. HAFEZ (1953) working with the same species has further demonstrated experimentally that prepupating larvae not only prefer drier sites but cooler sites too for their pupation. Therefore, it is probable that pupation takes place either at lower or higher levels in the soil wherever suitable sites are available. This was also observed in the laboratory; larvae when about to pupate move to the upper drier layers of the bran in the breeding jar or to the bottom when

the breeding medium is emptied on dry sand. It may be also concluded from the above experiments that the majority of larvae pupate in favourable sites nearest to their breeding grounds. In nature it was observed that pupae of *M. sorbens* mostly occur in the upper layers (about 2-3 cm. deep) of soil beneath the stools. In some cases, however, pupae occur deeper in the soil sometimes at 10-20 cm. deep. This occasional downward migration is probably for seeking more suitable sites. When on the other hand, such suitable sites (drier and cooler) are available on the upper layers of the brreeding medium and more accessible to the prepupating larva, upward migration probably takes place and the larvae pupate there, as occasionally observed in nature.

2. The duration of the pupal stage

The possible effect of temperature on the duration of the pupal period was tested in a series of experiments using 16, 24, 28, 32, 36 and 40°C. The humidity was kept constant in all cases at 70% R.H. The results are given in Table IX and

TABLE IX

Effect of temperature on the duration period of the pupa

Temperature in °C.	Number of individuals recorded	Duration period		
		Min.	Max.	Mean ± s.e.
16	58	13.25	16.50	14.91 ± 0.205
24	52	5.50	7.00	6.21 ± 0.057
28	42	4.25	5.00	4.56 ± 0.033
32	46	3.75	4.25	3.92 ± 0.023
36	45	3.50	4.25	3.86 ± 0.023
40	—	—	—	—

Figure 22. It was found that the shortest duration (average 3.86 days) at 36°C. At 40°C. all pupae failed to complete development and no emergence took place.

Comparing these results with those of FELDMAN-MUHSAM (1944) on *M. domestica vicina* (in Palestine), it seems that there is no much difference; thus at 17.5°C., 29°C. and 34°C. the average pupal duration was 13.25, 5.0 and 3.8 days respectively. HAFEZ (1941), working with *vicina* in Egypt, has recorded much lower figures of pupal duration (e.g. 2.46 days at 38°C. and 6.96 days at 13°C.) In *M. domestica*, on the other hand, LARSEN and THOMSEN (1940) in his wide range temperature experiments obtained figures of pupal durations (based on shortest durations and not average) that were distinctly higher (particularly at the lower temperature range) as compared with those of *sorbens*. For instance, at 15.1°C. the pupal stage in *M. domestica* lasted 24.9 days which is nearly twice that of *sorbens* at 16°C. At higher temperatures, e.g. 28°C., the minimum duration was 5.08 and 4.25 for *domestica* and *sorbens* respectively.

The hyberbola was constructed when the duration was 6.21 days at 24°C., and 3.92 days at 32°C.; the thermal constant was 85.05 day degrees and the developmental zero was 10.32°C. In the case of *M. domestica* (LARSEN and THOMSEN, 1940) and *M. domestica vicina* (FELDMAN-MUHSAM, 1944), the thermal constant and the developmental zero were 82.8 day degrees and 11.7°C. for the former and 87 day degrees and 11.3°C. for the latter, respectively.

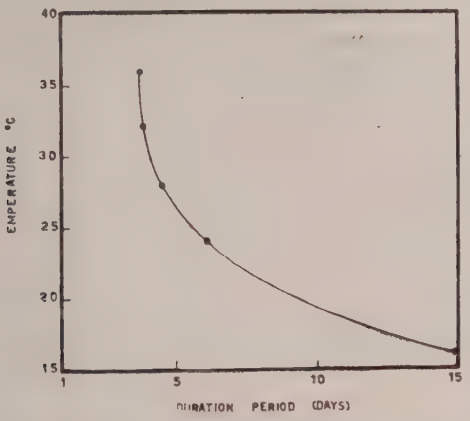

FIG. 22: The pupal duration at different temperatures.

Similarly, the effect of humidity on the duration of the pupal stage was tested. The relative humidities used were 0, 30, 50, 70 and 100% R.H. at both 28 and 36°C. From the results obtained (Table X) it seems that relative humidity has no significant effect on the duration of the pupal stage; thus at 30 and 100% R.H. the pupal stage (at 36°C.) lasted 91 and 93 hours respectively. In the case of *M. domestica* nearly similar observations were made by LARSEN (1943) who stated that no delay in development was seen at a low humidity.

TABLE X

Effect of humidity on the duration period of the pupa of M. sorbens

Temperature in °C.	Average duration at different R.H. in hours				
	0%	30%	50%	70%	100%
28	106	107	109	109	118
36	90	91	91	93	93

3. Pupal hatching at different temperatures

The influence of temperature on the number of pupae giving rise to adults, was tested in a series of experiments in which 6 temperatures ranging between 16 and 40°C. were used, relative humidity being kept constant at 70%. From the results obtained it was found that maximum emergence occurred between 24 and 28°C. when 94.7% of the number of pupae completed development and the adults emerged. However, at temperatures lower and higher than this range (e.g. 16 and 36°C.) about two thirds of the number of pupae (66.6 and 62.6% respectively) gave rise to adults. Therefore, under natural conditions, where temperature ranging from 24 to 28°C. is of common occurrence, it is expected that the greatest majority of pupae will successfully give rise to adult flies.

Flightless adults, with folded unexpanded wings, or deformed undistended bodies may occur. Others which have incompletely emerged out of their puparia are frequently met with. The rate of deformity among emerging flies as well as cases of incomplete emergence are recorded in the Table XI.

TABLE XI

The effect of temperature on the percentage hatching of the pupae

Temperature in °C.	Number used	Emergence				% proper	% Total
		Proper	Deformed	Incomplete	Total		
16	90	33	24	3	60	36.6	66.6
24	95	90	—	—	90	94.7	94.7
28	114	102	6	—	108	89.5	94.7
32	100	80	10	—	90	80.0	90.0
36	115	51	15	6	72	44.3	62.6
40	100	—	—	—	—	—	—

VI. SUMMARY

Biological studies have been conducted on the developmental stages of *M. sorbens* with special stress on the behaviour of the larva to some environmental factors.

The egg stage

The egg measures about 1.6 mm. in length. Under room conditions (31-34°C and 100% R.H.) the egg hatches after 6.25 hours. The incubation of the egg lasts more at lower temperatures (11.28 hours at 24°C.) than at higher ones (7.99 hours at 28°C.). Death occurs at the high temperature 43°C. and the low temperature 5.5°C. The developmental zero (the lower threshold of development) is at 10.1°C. The incubation period is slightly affected by humidity, however, longer durations

occurred at lower humidities (6.3-6.6 hours at 100% R.H. and 7.1-7.6 hours at 90% R.H.); none hatched at 85% R.H.

The highest percentage of egg hatching (fertile) is usually at 28°C. Higher temperatures, although accelerate development, yet they are more injurious to the egg (65% hatching at 40°C.) than lower temperatures (95% hatching at 16°C.). Also the 100% R.H. is most essential for successful egg hatching (96% at 100% R.H.), low hatching percentage occurs at the lower humidities (58% at 90% R.H). This is correlated with the shape changes undergone by the egg at the different humidities.

The egg loses about 30% of its weight and completely collapses after 60-minute exposure to 30% R.H. The loss in the first half hour, however, is twice that in the second half hour.

The larval stage

There are three larval instars; the first is about 1.8 mm., the second 3.8 mm. and the third 11.2 mm. in length. Their durations were 7, 14 and 40 hours (room conditions : 32°C.) respectively. Under controlled conditions the larval duration increased with decreasing temperature; shorter at higher temperatures (90 hours at 28°C.) and longer at lower temperatures (114 hours at 24°C.). A temperature as high as 40°C. seemed to prolong the duration to about 73 hours. The developmental zero was at 9.2°C.

Large sizes were obtained from food containing yeast.

The larva has a great power in penetrating hard and soft soils, about 1000 times its own body weight in its foremost thrust.

The larval behaviour

The reactions of the larva (feeding and prepupating) to several environmental factors : humidity, temperature and smell were studied under laboratory conditions in an arena divided into two halves.

Humidity reactions: The feeding larva preferred humidities near saturation. It was less sensitive or indifferent to humidities below 50% R.H. The intensity of the reaction increased at the higher humidity ranges. The prepupating larva preferred humidities within the range 50-60% R.H. and became less sensitive to humidity at the higher and lower ranges, the intensity of the reaction depending on the humidity difference offered. Both larvae, however, showed no adaptation to the humidity to which they had been previously exposed.

Temperature reactions: The larva strongly avoided 33°C. in 50% R.H. but did not avoid 40°C. in direct contact with water. 15°C. was avoided. It was indifferent to temperature differences between 16-29°C. at 50% R.H. and 16-40°C. in water contact. The prepupating larva was indifferent to temperature differences between 16-25 C. (50% R.H.). Both larvae showed no adaptation to temperature to which they had been previously exposed.

Smell reactions : Human excrement, milk, ammonia, acetone, indole, skatole and alcohol scented sides were preferred to the neutral side of the arena, and the larva was repelled by the smell of acetic and formic acids. The prepupating larva seemed to have a weaker sense of smell as indicated by its indifference to the smell of acetic and formic acids and ammonia.

The orientation mechanisms contributing to the behaviour of the larva towards such environmental factors seem to be klinotaxis, klinokinesis and orthokinesis.

The pupal stage

The pupa is about 5.9 mm. in length, and has a chestnut brown coloured pupal case. Pupation takes place at varying depths in the soil beneath the stool apparently wherever a suitably drier site is located by the larva. This latter may pupate in the upper layers of the breeding medium if these are nearest and suitably dry.

The pupal duration is longer at lower temperatures (6.21 days at 24°C.) and shorter at higher temperatures (4.56 days at 28°C.), with more pupal hatching at temperatures between 24 and 28°C. However, the pupae die at 40°C. Humidity seems to have no significant effect on the duration of the pupa, thus at 0% and 100% R.H. the durations are 90 and 93 hours (at 36°C.), respectively.

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ECOLOGICAL AND BIOLOGICAL STUDIES ON *ACRIDA PELLUCIDA* KLUG, IN EGYPT

[*Orthoptera* : *Acrididae*]

(with 4 Text-Figures and 6 Tables)

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I. INTRODUCTION

Locusts and grasshoppers stand first and foremost as pests of great economic importance, and have always stimulated intensive research. Their biology has received a good deal of attention, and their breeding in the laboratory has been dealt with by several authors, e.g. CAROTHERS (1923), FRY (1927), ALBRECHT (1953). In 1932, BALLARD and his co-workers have made extensive field and laboratory observations on the biology of *Schistocerca gregaria* in Egypt. The notable biological work of HAMILTON (1936, 1950) on *Locusta migratoria*, *Schistocerca gregaria* and *Nomadacris septemfasciata* under controlled conditions is worthy of mention. Other authors have studied certain biological aspects of different species of Acrididae, e.g. CRIDDLE (1918) on the egg-laying habits, FEDOROV (1927) on copulation and oviposition, DRAKE (1945) on oviposition and adult survival.

On *Acrida*, which is an indigenous grasshopper widely distributed in Egypt, no work here nor in other countries seems to have been carried out (apart from taxonomical). Numerous authors, however, have recorded some species of *Acrida* among the injurious insects in different countries (Ballard, 1914; Zacher, 1920; Pelaghias, 1931; Yang, 1937; Hamai, 1937). In view of this, and as a contribution to our knowledge of Egyptian grasshoppers, some ecological and biological studies on *Acrida pellucida* Klug, the most common species of this genus in Egypt, were undertaken in the department of Entomology, Faculty of Science, Cairo University. The present paper deals with the adult stage. The developmental stages (i.e. the egg and nymphal stages), on the other hand, will be dealt with in another paper.

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II. GEOGRAPHICAL DISTRIBUTION

The genus *Acrida* was reported from different parts of the world. It occurs throughout Africa, Canary Islands, Cape Verde Island, Madagascar, the southern part of Europe and all the Mediterranean Islands, throughout the southern half of Asia (where its northern limit follows roughly the annual isotherm +8°C.), Japan, Australia and the Australasian Archipelago. Within this extensive area the genus is restricted in its distribution to plains, and the distribution areas of the different species are limited by mountain ranges, even some low ones forming barriers.

The different species of *Acrida* are poor fliers, ecologically connected with grasslands of every type from dry to relatively wet. Their body structure indicates that the adaptation of the genus to grasslands is an ancient one, and that the development and formation of the genus took place in the geological time when grasslands not only existed, but flourished, possibly during the Pliocene to the Pleistocene period. At the present time some species of *Acrida* are distributed in forest zones, but even in this case they remain connected with grass habitat.

As to its distribution in Egypt, *Acrida* is fairly common throughout our country. A review of the literature reveals that numerous authors have collected their specimens from different parts of the Egyptian territory. It was recorded from Sinai, Siwa Oasis, Baharia Oasis, Marsa Matruh, Burg El Arab, and numerous other localities in the Nile Valley (Klug, 1830; Werner, 1905; Innes, 1929; Uvarov, 1943; Dirsh, 1949).

III. MATERIAL, METHODS AND TECHNIQUE

For studying the biology of *Acrida pellucida* a stock was started from egg-pods laid in the laboratory by insects collected from the field as adults or as nymphs.

This stock was kept at 35°C. and 40-85% R.H. Sufficient fresh food consisting of *Cynodon dactylon* and *Imperata cylindrica* was supplied daily. Glass cylinders of 900 cc. capacity were used for studying the biology of the early instar nymphs, while glass museum jars of 6500 cc. capacity were used for the work with elder instars and the adults. Both the cylinders and jars were fitted with suitable wire-gauze lids. Each jar or cylinder was provided with a thin layer of clean dry sand at its bottom and a dry *Casuarina* branch for the insects to rest on. In the case of adults, the jars were provided with suitable pots filled with moistened sieved sand to serve as an ovipositional ground.

For controlled humidity, the jars were fitted with suitable greased glass lids. Four glass vials (6 x 12 cm.) containing suitable amounts of KOH solution and fitted with wire-gauze stoppers were put each in a corner of the jar and were fixed in position by sand. Different concentrations of KOH solution were used to produce different relative humidities (Buxton and Mellanby, 1934). Excreta and food remnants were cleared daily, and the jars were ventilated for 30-60 minutes after changing the food. The potash solutions and the sand were renewed every fortnight. Three humidities (30, 70, and 90%) were used. Jars of 90% R.H. received more attention due to the development of moulds, and were therefore renewed weekly.

Three series of experiments were undertaken : a series in field cages, another series in cages put inside a roofed screened insectary, and a series under controlled conditions. Cages used for the latter work were electrically heated and thermostatically regulated. In all series observations were made daily.

Pots containing the egg-pods were removed directly as they were observed, put in the respective incubator or cage, and their sand was kept moistened.

IV. BIOLOGY AND ECOLOGY

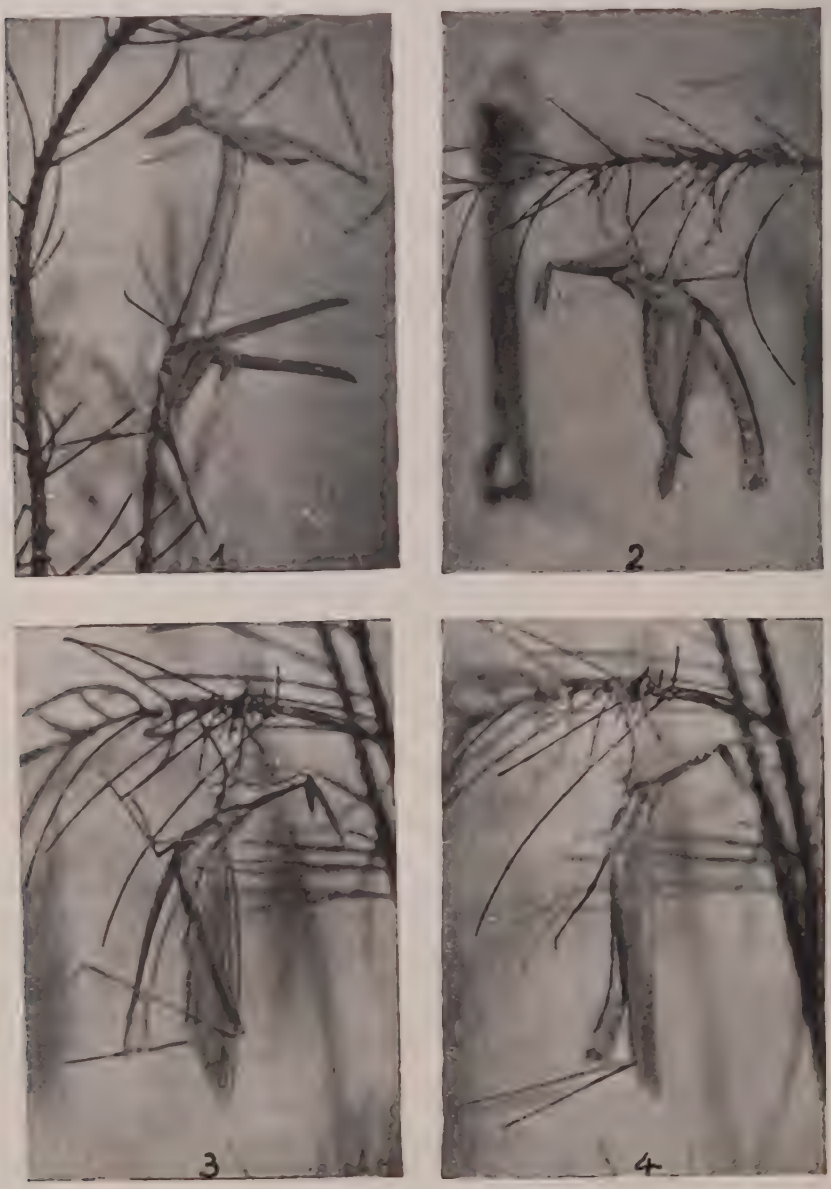
1.Emergence of the adult

The final moult by which the hopper reaches the adult stage does not exhibit any substantial difference from the preceding moults, though outwardly this transformation seems more striking owing to the development of the wings (Figs. 1-4).

The last instar nymph selects a situation that enables it to hang freely, and starts to adjust itself and fix its legs firmly to it. It hangs with the head downward, yet several cases were observed where the insect fixed itself horizontally onto the roof of the cage.

Being firmly attached to the support, the hopper moves its abdomen rhythmically as a result of peristaltic pressure motions. The thoracic region becomes relatively inflated by excessive pressure and therefore the wing pads part from each other. Due to this excessive pressure the cuticle is slit along the mid-dorsal line of the cephalic and thoracic regions. At this moment the insect draws its antennae upwards

to lie against the frons, and thence starts to glide slowly out of its old cuticle, aided by gravity and peristaltic movements.



FIGS. 1-4: The emergence of the adult.

When the antennae are freed from their "sleeves" they remain lying close to the frons until the fore and mid legs are also released. By this time the antennae move away to hang down. The antennae, palpi and the tarsi of the released legs are all moved at intervals. At the same time the moulting of the abdomen is going on, with the long hind legs dragged out along the sides and the wings on the dorsum. The wings, when released, extend over the abdomen to the posterior margin of the fifth segment, while before this moult they hardly covered the anterior half of the third tergum. Soon, the wings gradually curve away till their apices point downwards. The tegmina now overlie the wings instead of being overlain by them before this moult.

When the hind knees appear out of the old cuticle, the moulting of the abdomen stops, and the remaining parts of the hind legs are then dragged out and released, and the tibiae are folded close to their femora. Now the insect is held to the exuvium only by its abdominal apex. Then it swings towards the support to get hold of it and then snatches its abdomen off the exuvium.

An average of 20.5 minutes is spent since the splitting of the cuticle till the insect is completely free. Now the insect hangs quiet with the head upwards. Besides the pressure waves sent through the abdomen, pressure is now also applied at intervals to expand the wings. These gradually smoothen, increase in area and stand vertically, those of both sides close to each other. When completely expanded, they remain as such for 2-3 minutes and then the hind wings are folded into their usual plaits, with the tegmina ensheathing them. The whole process of wing expansion and folding lasts about 22 minutes.

The insect, now acquiring the adult shape, remains in a standstill state for some time, with local movements of the appendages.

2. Sexual maturity and the pre-oviposition period

By acquiring the organs of flight, after the last moult, the newly emerged adult does not reach the final stage of its individual development, since it is not yet ready to pair, and a certain period is required for the attainment of sexual maturation. Unlike swarming locusts, *Acrida* exhibits no external morphological signs at sexual maturity, the latter is attained without changing the body coloration. The swarming phase of *Schistocerca gregaria*, on the other hand, changes its colour from greyish to pink and finally to yellow, while its solitary phase does not change its greyish colour (BALLARD, 1932). Also no changes occur in the coloration of the hind wings or the pronotal and head stripes. This finding may be of taxonomic significance, since UVAROV (1943) is inclined to believe that the variations found in the coloration of the hind wings of specimens from the different localities may probably be due to sexual maturity.

The time required to reach sexual maturity in field cages (calculated as the preoviposition period) varies according to the season (Table 1). It is shortest in adults emerging in summer and increases gradually in those emerging late in the

season. It reaches its maximum in individuals that pass the winter as adults, since they will not start to pair or deposit eggs until the following spring. In these individuals the development of the genital products seems to stop, a condition which has been called "imaginal diapause" (Pospelov, 1911, 1922).

Table I

The pre-oviposition period in field cages

Month of emergence	Pre-oviposition period (in days)		
	Maximum	Minimum	Average
February	75	47	55.8
March	49	29	33.5
April	35	21	26.4*
May	27	15	20.1
June	24	13	19.1
July	21	13	17.3
August	24	14	18.0
September	26	18	20.8
October	—	25	—
November	—	26	—

Since copulation precedes oviposition, the sexual maturity, at least of the males, is naturally earlier than the oviposition time, that of the male being determined by its first copulation act. Males emerging during June and July generally begin copulation after 7-9 days of their emergence. This period is longer in colder weather, reaching an average of 14.7 days in males emerging in October.

3. Copulation

Before copulation takes place, a process of courting usually occurs. The male approaches the female and strokes her with his antennae for some time. Then it jumps, or more often creeps, to sit on her dorsum anteriorly. If the female is not ready for pairing, she kicks him away by excited jerks of her hind legs. The male, being insistent, may repeat his trial several times. Occasionally, however, the female was observed to begin the courting by herself.

a. *Mating*

When there is response, the male moves posteriorly to secure a position suitable for pairing, since he is smaller in size than the female. In doing so, the male rests indifferently either on the right or on the left side of the female, with his abdomen lowered and twisted sideways. During this time the male bends his subgenital plate backwards to expose his penis which is now protruded and directed upwards and forwards. He then depresses the female's subgenital plate using his raised

cerci aided by the anterior hooks of his epiphallus. Thence the penis is forced into the female genital chamber and is inserted into the spermathecal orifice. As a result, the male subgenital plate is pressed tightly against the ovipositor of the female.

In position, the male rests firmly holding with his fore and mid legs on the female's body. His hind legs are held in various positions and take little or even no part in pairing. The male's antennae are commonly lowered to touch the female. During copulation, the respiratory movements of the male are more pronounced than those of the female which appears more calm. Towards the end of the process the respiratory movements of the female are more enhanced, and she starts to jerk her hind legs gently at intervals. This jerking action is repeated later on with growing energy till at last she succeeds to dislodge the male. This usually ends the process, yet it may take the male away of the right position while his terminalia is still firmly lodged in the female. The female then moves ahead dragging the male which struggles to gain hold in the right position again. However, the male may himself end the process without the female disturbing him. The penis is retracted off the female, and by repeated retractions and protractions, the aedeagus is returned into its normal position.

Inbetween the lower valves of the ovipositor of a female, just after copulation, a fine drop of a milky-white, jelly-like liquid is observed which indicates the true insemination of the female. This substance hardens gradually and becomes yellowish and brittle, and all of its traces may be lost within a day or more according to the activities of the female.

b. *Duration of the copulatory act*

In case of individuals kept at 35°C. (R.H. 40-85%) the duration of the copulatory act varies between 50-71 minutes, with an average of about one hour. In field cages and in the insectary, copulation was not observed except when the weather was sufficiently warm, and the average duration of the process was 64 and 70 minutes, respectively. The duration of this act in *Schistocerca gregaria* ranges from 10-50 minutes in some cases, while in other cases above 24 hours (Ballard, 1932). In *Anacridium aegyptium*, copulation lasts not less than 18 hours, but often longer, sometimes even two days or more (Fedorov, 1927).

c. *Number of copulatory acts preceding each oviposition*

Reaching sexual maturity, adult *Acrida* starts pairing, and the act occurs only once before the female lays her first egg-pod. Thence, after a period, another copulation takes place after which the female oviposits for the second time, and so on. This differs from that recorded for *Schistocerca* where a series of copulatory acts, sometimes reaching ten times, precedes each oviposition (Ballard, 1932). An inseminated female *Acrida*, on the other hand, will not allow any male to sit on her dorsum. In few cases, however, a male may secure position on such a female, but the copulatory act is not maintained. Sooner or later he feels failure and alights.

d. *Interval between pairing and oviposition*

After copulation, female *Acrida* is not ready to lay her eggs soon, but a varying interval is passed before oviposition. In all our experiments not a single female oviposited directly after copulation or even on the same day. In this respect it differs from *Schistocerca* where the female is ready to lay her eggs just after the last copulation, though oviposition may sometimes be retarded (BALLARD, 1932).

The average period at 35°C. (R.H. 40-85%) spent after copulation till oviposition is 5.8 days, with a minimum of 2 days and a maximum of 9 days. In field cages the average is 6.4 days during the summer, with a minimum of 5 days and a maximum of 11 days. In the insectary the average interval is 8.6 days in summer with a minimum of 7 days and a maximum of 11 days.

e. *Interval between oviposition and the next pairing*

After depositing her eggs, the female is not directly ready for recopulation, but the latter act does not start before the elapse of some time. In *Schistocerca*, on the other hand, recopulation may take place directly after oviposition, especially under field conditions (BALLARD, 1932). In the majority of cases, recopulation starts on the next day after oviposition. In few records recopulation occurred late on the same day, after at least six hours of oviposition.

4. Stridulation

Male *Acrida* is able to produce sounds by friction of the hind femora against the tegmina. The pitch of the sound thus produced and its tone are fairly specific, and it is quite easy for a worker to distinguish the stridulation of *Acrida* in the field during a hunt.

In our experimental cages, female *Acrida* was also observed to stridulate, but the sound thus produced differs from that of the male, this being more harsh and generally shorter than that of the male.

5. Soil selection for oviposition

A gravid female, ready for oviposition, moves on the ground of the cage with her abdomen curved downwards. It then stops and starts to drill a hole in the soil. Soon, the female may withdraw her abdomen without depositing her eggs, or even before going so deep in the soil. Moving slightly, it starts to dig in a new situation. This may also be deserted to a third position and so on. In her search for a suitable situation for egg-laying, female *Acrida* was observed to drill numerous holes, sometimes as many as 14, in the last of which the eggs were deposited. Similar behaviour of digging numerous empty pits was also recorded for *Schistocerca* (BALLARD, 1932). More often, however, the female deposits her eggs directly in the first pit.

To test the soil selection of this species, pots filled with different types of soil were offered to the female to oviposit in, promoting equal possibilities of choice. Dry sand was avoided for oviposition, though numerous empty pits were dug in it, probably for seeking a moist layer below it. Soil was also avoided even when moistened, but when mixed with sufficient sand (ratio 1:1) it was accepted. Moist sand and alluvial soil proved to be the best grounds for oviposition of *Acrida* in captivity, though numerous empty pits were also encountered in them.

6. Oviposition

To follow the intimate process of egg-laying, a cage similar to that originally designed and described by FEDOROV (1927) was constructed after being modified to meet the special needs of the insect in question. Female *Acrida* is larger in size, with longer and more slender abdomen than *Anacridium aegyptium* to which FEDOROV has designed his cage. Therefore, the upper chamber of our cage is wider, and the lower glass panes are 25 cm. high and only 5 mm. apart. A female ready for oviposition is transferred to this cage where it is supplied with fresh food.

a. *The digging operation*

The wooden floor of the upper compartment of the cage in which the gravid female is enclosed, has a median longitudinal slit opposite to the space between the lower glass panes, this space being filled with moistened sand. The insect moves here and there, with its ovipositor working in vain in the wooden floor, till at last it meets with the slit where sand is present and in which the pit is to be made.

Standing ready to dig, the female rises high on her fore and mid legs, while the abdomen is arched so that its apex is directed nearly vertical to the soil surface. Then rhythmic work of the ovipositor starts. The upper and lower valves are first drawn together, the tip of the abdomen pushed downward and, being in the soil, the valves are pushed apart to the greatest possible extent. In so doing the recurved apices of the valves remove the soil particles towards the periphery of the excavation. By repeating this work a hole is made, and the ovipositor, working incessantly, sinks gradually deeper and deeper in a nearly vertical direction. During this work the abdominal apex rotates alternately to the right and to the left. The angle of this rotation usually falls around 90° on each side, but it was repeatedly observed to go further that the dorsal and ventral ovipositor valves replaced each other in position. The rotation in *Anacridium* is usually about 90° on each side, and such complete rotation was not mentioned (FEDOROV, 1927).

Every now and then the abdominal apex is slightly retracted upwards, with the ovipositor still working and rotating. This is done seemingly to widen the hole, smoothen its wall and make the soil particles more compact and the hole more uniform. As the ovipositor goes deeper into the soil the abdomen is extended gradually. Its length is added to by the expansion of the inter-segmental membranes

4-5, 5-6, 6-7 and 7-8. Towards the end of the digging operation these membranes become so strongly stretched and nearly transparent. When fully extended, these inter-segmental membranes measure on an average 1.6, 5.5, 4, and 2.3 cm., respectively.

Membranes 2-3 and 3-4 are hardly one millimeter each. The depth of the excavation measures about 15-17 cm., while the length of the normal female abdomen is about 4.5 cm. In *Anacridium* the abdomen is originally about 3.5 cm. and is extended to reach 9-10 cm.

The average time taken in digging a hole is about 45 minutes, yet it may be exceptionally prolonged to 2 hours and 33 minutes in normal sand with no obstacles. Concurrently with the underground burrowing, the thorax of the female is gradually lowered till it is nearly pressed against the soil, and the insect becomes then deeply motionless.

b. *Deposition of eggs*

Reaching the satisfactory depth, the ovipositor stops for a while, then the apex is lifted slightly upwards (about 0.5 cm.). Strong pulsating actions appear in the terminal segments, and a silvery white secretion soon bathes the ovipositor and fills the bottom of the hole in the form of a foamy mass.

During the actual oviposition the valves are first drawn in, then project again holding an egg. This issues through the excision in the lower valves and the subapical excision of the upper ones. The valves retain the egg for a short time, then it is pushed into the hole. The eggs are laid singly and are arranged in the hole beside and over each other in an oblique manner, with the micropylar end pointing downward and anteriorly. The angle of their inclination ranges about 50-60° from the horizontal plane.

During egg-deposition the abdomen contracts gradually but never rotates. Contraction starts distally and is more pronounced in the membrane 6-7. Once the latter reaches 1.5 cm. membrane 5-6 is still 4 cm. long. When 6-7 is restored to its normal condition, 5-6 measures 2.5 cm.

The actual egg-deposition lasts an average of 41 minutes. After laying the last egg in the pod the insect starts to emit only the foamy secretion to form the stopper, a process that takes an average of 32 minutes. No external sign of retracting the abdomen occurs till all the membranes are restored to their normal condition. Thence the insect begins to raise its breast, and so gradually the abdomen arches out. During the retraction of the abdomen the foamy secretion darkens gradually to acquire a reddish-brown colour. Near the exit of the pit the retraction of the abdomen is very slow that about 16 minutes are spent in the last 1 cm. of the stopper. Here the secretion is already brownish with its bubbles much finer than elsewhere.

Filling the pit with secretion nearly to the soil surface, the female draws her abdomen away. Using her hind legs it starts to collect soil particles onto the orifice. Now and then the insect presses the collected particles onto the pit, and the process is continued till the hole is quite obliterated.

c. *Average time taken in laying an egg-pod*

At 35°C. (R.H. 40-85%) the average time taken in laying a pod is 128 minutes, with a minimum of 103 minutes and a maximum of 162 minutes. In field cages and in the insectary the period necessary for this process ranges about this average, since oviposition takes place usually when it is sufficiently warm.

d. *Number of egg-pods laid by a single female*

In field cages the average number of pods per female is 4.7 pods. The minimum is one pod and the maximum is 9 pods, but the more prevailing number is 6-7 pods. In *Schistocerca* this number varies between 1-6 pods for each female (BALLARD, 1932).

In the insectary, the average number is 2.8 pods per female, with a minimum of one pod and a maximum of 5 pods. Under controlled conditions (35°C., 40-85% R.H.) the average is 2.4 pods per female. The maximum is 4 pods, but the prevailing number is 2-3 pods. Under such conditions the insects are relatively short lived and seems to have no chance for more layings.

e. *Intervals between the successive layings*

In field cages the intervals between the successive layings (table II) vary considerably. The average shortest interval (6.3 days) lies between the first and second pods, and the longest (12.8 days) between the last two pods.

TABLE II

Intervals between successive ovipositions in field cages

	Interval in days		
	Minimum	Maximum	Average
Between 1st and 2nd	4	9	6.3
Between 2nd and 3rd	3	10	6.5
Between 3rd and 4th	4	11	7.8
Between 4th and 5th	5	11	6.7
Between 5th and 6th	5	12	8.8
Between 6th and 7th	5	17	12.8

In the insectary the intervals (average) between successive layings are also variable, ranging between 8-12 days. Under constant conditions (35°C., 40-85% R.H.) the intervals (average) between the successive ovipositions do not exceed 7.2 days.

f. *Number of eggs laid by a single female*

The number of eggs laid by a female in its successive pods does not follow a regular increasing or decreasing order. The following is an example of a female

(in field cages) which laid 9 pods containing 39, 62, 89, 80, 67, 59, 70 and 56 eggs, respectively. The total is 613 eggs which is the maximum number for a female. For *Schistocerca* the maximum is 281 eggs per female (BALLARD, 1932).

The average number of eggs per female in field cages is 416 eggs. In the insectary and at 35 °c this average is about 267 and 155 eggs respectively.

g. *The oviposition period*

The time passed since the first laying till the last one depends chiefly on the life span of a healthy female. Its average in field cages is 35 days, with a minimum of 5 days in a female laying 2 pods, and a maximum of 59 days in a female laying 7 pods and living in the autumn.

h. *Post-oviposition period*

In general, female *Acrida* does not die directly after depositing its last pod, though this may sometimes happen. Normally, a period of its life, the post-oviposition period, is passed before death is reached. During this period the insect is generally sluggish and less active. At 35 c this period varies between 2-16 days, with an average of 8.3 days. In field cages it is somewhat longer, reaching 20 days with an average of 11.4 days.

7. Food plants and food preference

The normal food of the Acrididae in general comprises the green parts of various flowering plants. As regards the selection of food-plants, the various species exhibit wide differences in their tastes. Whereas a species is grass-feeder another may be broad-leaved-plant-feeder, and still another may be mixed-plant-feeder. Moreover, within each of these groups a species may exhibit further discrimination. Thus *Locusta migratoria* is closely connected in its feeding with the weed *Phragmites communis* (UVAROV, 1928), while *Colemania sphenerioides* exhibits a special preference for millet and allied plants (COLEMAN, 1911) which are very little eaten by Acrididae. These food preferences are observed only when there is a possibility of choice, but when the preferred plants are absent, the same Acridid may feed on many other plants, not even avoiding those which are directly poisonous. Thus *Dociostaurus marcoccanus*, when there is no other vegetation, feeds on *Peganum harmala* with fatal results (LA BAUME, 1918).

Close investigation of the natural habitat of *Acrida* reveals the fact that this species is a grass-feeder, possessing a relatively limited range regarding the selection of food plants. In these areas the vegetation is mainly of the graminaceous type, being largely dominated with *Imperata cylindrica*, *Cynodon species* and *Polypogon monspeliensis* which grow wildly in waste areas around the cultivated fields.

In addition, adult *Acrida* may also be encountered in cultivated fields. Their presence in these areas must not be readily accepted as absolutely for feeding on

the growing plants, but probably associated with other factors such as seeking shelter or rest, or possibly for feeding on wild herbs that grow among these plants.

The fact that the nymphs are almost always restricted to wild areas of *Cynodon* and *Imperata* may lead to the general conclusion that these are the most favourable food plants selected by them. In fact they proved to be so in captivity. Both *Cynodon dactylon* and *Imperata cylindrica* were readily devoured, in equal preference, by all nymphs which developed normally, and by adults which reproduced at their highest fecundity.

To test the food preference of this species, the seedlings of 14 Egyptian crops were offered to the insect singly and as a pure diet. These were : clover (*Trifolium alexandrinum*), wheat (*Triticum vulgare*), barley (*Hordeum vulgare*), maize (*Zea mays*) gulban (*Lathyrus sativus*), rice (*Oryza sativa*), cotton (*Gossypium barbadense*), bean (*Vicia faba*), lupine (*Lupinus termis*), lentils (*Lens esculenta*), fenugreek (*Trigonella foenum-graecum*), flax (*Linum usitatissimum*), lablab (*Dolichos lablab*), and chick-pea (*Cicer arietinum*).

Out of these 14 plants, the last eight proved detrimental. They were scarcely eaten except for very few parts which were partly nibbled. Observations on the hoppers of this species suggest that they have the same food taste, and none of them was able to moult or even survive for a long period on a pure diet of any of these plants. In presence of *Cynodon* or *Imperata* these plants were absolutely rejected.

Rice was fairly eaten in normal voracity by both adults and hoppers. Adults, however, all failed to attain sexual maturity. The majority of the first instar nymphs were able to moult once only and died later. Few of these were able to undergo a second moult, but also failed to proceed furthermore. The same was observed when starting with older nymphs previously fed on *Imperata* or *Cynodon*. In presence of these latter plants rice was fairly fed upon, and the insects most probably got a mixed diet.

Adults bred on *Lathyrus*, though lived fairly long (average of 48 days in spring in field cages) were unable to lay eggs. Newly hatched nymphs developed well on this diet, yet the stages were relatively longer, and all individuals failed to reach the adult stage. This plant was also fed upon in presence of their preferred diet.

Clover, wheat, barley and maize were all eaten normally. The nymphs reached the adult stage, though the stages were somewhat longer especially on maize diet, and the adults attained sexual maturity. The fecundity of those bred on clover was too near to those bred on *Imperata* or *Cynodon*, while on the other plants the fecundity was very low, being sometimes about one fourth of the normal average. As to longevity, adults bred on this group lived for a nearly normal span, but it has to be mentioned that young seedlings of maize (less than about 20 cm. high) are fatal to all stages.

8. Seasonal abundance

Studying the population of *Acrida* in the field, it was found that adults and

hoppers are encountered nearly all the year round. They are less frequent in winter, when they are seen only in warm periods and by disturbing the vegetation where they are to be expected. The males of this species are generally much more frequented in the field than females. This may be attributed to their being stronger fliers and to their usual habit of stridulation which directs attention to their hiding places. The females, on the other hand, are more sluggish probably due to their larger size and partly due to their being gravid. They usually try to escape notice by standing still amongst the vegetation, in which case they are easily overlooked. This behaviour differs from that of the males which, when feeling danger, try to fly away and so attract notice.

During the summer and autumn this species manifests itself in greater abundance. This may be due to the fact that warmth during this period accelerates the hatching of eggs and the development of the hoppers, thus giving a continual supply of adults.

9. Longevity of the adult

For this purpose, observations were made by rearing separate pairs in field cages. Leaving out of consideration such examples in which the insect died prematurely before copulation or oviposition, observations have shown that the longevity

TABLE III

The average longevity of adults in field cages

Month of emergence	Average longevity (in days)	
	Male	Female
February	114.6	100.2
March	107.1	97.0
April	84.2	85.6
May	80.0	83.1
June	65.2	64.4
July	63.8	62.8
August	80.3	60.1
September	118.0	112.5

of adults varies according to the season when they emerged (Table III). The monthly means of temperature and humidity during the years 1953 and 1954 when these observations were made are given in Table IV.

The life span of adult *Acrida* is shortest in summer and longest in autumn. The autumn adults, especially those emerging late in the season, spend the winter in an imaginal diapause which naturally lengthens their life. Some females died some time after laying the first egg-pod, but unless signs of parasitism were evident it was impossible to separate those which died of a natural cause from those which died from some other causes.

TABLE IV

The monthly means of temperature and humidity

Year	Temperature and relative humidity		Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
1953	Temp.	Mean	10.9	13.6	13.9	19.8	24.6	27.0	28.8	27.3	24.6	22.7	16.2	12.6
		Mean maximum	20.5	22.0	21.5	28.4	33.4	35.6	37.1	35.0	31.9	30.1	24.2	20.1
		Mean minimum	5.1	7.8	7.7	12.2	15.9	19.1	21.4	20.1	18.1	16.2	10.1	7.0
	R. H.	8 hours	71	73	61	61	53	61	68	71	74	77	82	80
		13 hours	33	40	36	29	23	27	26	32	37	36	38	46
		20 hours	62	61	56	49	37	40	43	50	59	60	63	68
		Mean	66	67	58	55	45	50	56	60	66	68	72	74
1954	Temp.	Mean	11.2	13.5	17.1	19.4	24.5	26.6	28.2	27.9	24.7	22.7	17.9	12.6
		Mean maximum	20.6	22.1	25.7	27.7	33.7	34.9	35.1	35.2	31.9	30.9	26.8	20.4
		Mean minimum	5.1	6.8	9.6	11.5	15.3	18.9	21.4	21.5	18.1	16.1	11.5	7.3
	R. H.	8 hours	70	68	70	60	50	72	72	73	75	73	77	84
		13 hours	34	28	25	25	19	59	28	35	37	32	36	41
		20 hours	57	53	61	47	38	39	49	55	59	59	62	85
		Mean	64	60	60	53	44	56	60	64	67	66	70	84

Similar observations were conducted in the insectary and parallel results were obtained. Longevity was somewhat greater, apparently due to the conditions being less severe and the temperature being lower in the insectary. This general comparison shows that direct sunlight and other climatic factors have an important bearing on the life of this species.

The life span of adults was also studied under controlled conditions :

a. *Effect of constant temperature and fluctuating humidity on longevity*

The constant temperatures used in these experiments were 30 and 35° ±, and the humidity was left to fluctuate freely between 40 and 85%. The results thus obtained are summarised in Table V.

TABLE V

Longevity of adults under controlled temperature and fluctuating humidity

Temperature in °C.	Longevity (in days)					
	Mininimum		Maximum		Average	
	Male	Female	Male	Female	Male	Female
30	26	40	103	98	73.4	66.5
35	16	17	97	58	41.3	32.6

b. *Effect of constant temperature and controlled humidity on longevity*

Three humidities (30, 70, and 90%) were used in these experiments which were all performed at 35°C. (Table VI).

TABLE VI

Longevity of adults under constant temperature (35°C). and controlled humidity

	Longevity (in days)					
	30%		70%		90%	
	Male	Female	Male	Female	Male	Female
Minimum	18	14	28	26	17	21
Maximum	48	67	104	80	74	78
Average	30.5	37.6	49.1	40.3	43.0	48.0

From the data obtained it may be concluded that male *Acrida* generally lives longer than the female. The life of both sexes is, however, greatly affected by the season and the prevailing temperature. Under low temperature the longevity

is fairly great, while it is considerably reduced at high temperature. As regards humidity, it seems that the optimum range of relative humidity for *Acrida* is confined between 70 and 90%. Under dry conditions the individuals can hardly withstand drought. These results agree with the nature of the breeding grounds of this insect where dense vegetation provides shelter and promotes high humidity.

V. SUMMARY

1. — *Acrida* is an indigenous grasshopper, found all the year round, especially abundant in summer and early autumn. It is almost always restricted to waste areas around fields, but may also be encountered among cultivations.

2. — It is a grass-feeder particularly preferring *Cynodon* and *Imperata*, both being the more dominant plants in its breeding grounds. Besides these, experiments have shown that it also feeds voraciously on the seedlings of rice, clover, wheat, barley, maize and gulban, all of which are of economic importance in Egypt. On the other hand, seedlings of cotton, bean, lentil, lupine, chick-pea, fenugreek, lablab and flax all proved to be unsuitable as food for this species.

3. — In field cages the pre-oviposition period reaches its minimum (13 days) in June and July. In winter the adults are subject to an interruption in their development (imaginal diapause). Sexual maturation of this species is attained without any change in the colour of wings or any other external morphological sign.

4. — A male and a female remain in copula for an average of one hour. A single insemination is sufficient for each laying.

5. — Both sexes of *Acrida* are able to stridulate by friction of the hind femora against the tegmina.

6. — The male lives generally longer than the female, the longevity of both being greatly affected by temperature. At 35°C. (40-85% R.H.) the average longevity is 41.3 days for the male and 32.6 days for the female. At 30°C. (40-85% R.H.) this average rises to 73.4 days for the male and 66.5 days for the female. That is, with a decrease in temperature from 35 to 30°C. the longevity of both sexes is nearly doubled. Humidity has also but a weaker influence on longevity. The more favourable relative humidity seems to be about 70% at 35°C.

7. — The maximum number of pods laid by a single female in field cages is 9 pods containing 613 eggs. The average number of eggs per female is 416 eggs. At 35°C. the maximum number is 285 eggs. Moist sand and alluvial soil were the highly preferred grounds for oviposition in captiviy.

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STUDIES ON THE EGG AND NYMPHAL STAGES OF *ACRIDA PELLUCIDA* KLUG, IN EGYPT

[*Othoptera* : *Acrididae*]

(with 2 Text-Figures and 6 Tables)

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I. INTRODUCTION

In a previous paper (*see* this Bulletin, pages 163-181) the authors have undertaken some ecological and biological investigations on adult *Acrida pellucida* Klug, in Egypt. As an extension of these studies, the biology of the egg and nymphal stages of the same species are dealt with in the present paper.

Reviewing the literature it appears that Acridid developmental stages have attracted the special interest of many workers. Of these we may mention the work of CRIDDLE (1924) and DOVNAR-ZAPOLSKII (1927) on the larval stages, that of MALTZEV (1925), ANDREWARTHA (1942-1945) and MATTHÉE (1951), on Acridid eggs. Valuable information, however, on these stages is included in the works of several authors, notably FAURE (1923), CAROTHERS (1923), FRY (1927), UVAROV (1928), KEY (1936), HAMILTON (1936, 1950) and ROONWALL (1936, 1952). BALLARD and his co-workers (1932), working on *Schistocerca gregaria* in Egypt, have conducted extensive field

and laboratory observations on the egg and nymphal stages of this species. Further observations on the same species in Egypt have also been undertaken by MISTIKAWY (1936). A recent work has been done in this country by KAHALIFA (1956) on the egg-pods of some Egyptian grasshoppers. As previously stated, however, no work on *Acrida* seems to have been carried out here nor in other countries, a state of affairs which stimulated the authors to undertake the present study.

The methods and technique used are the same as those described in the authors' previous paper on the ecology and biology of this species.

II THE EGG STAGE

1. The egg-pod

A freshly laid egg-pod is very delicate, soft and moist. It is then almost impossible to dig it out safely, but later on it becomes enough hard with a firmer consistency. As in other Acridids, the pod, consists of a lower egg-mass and an upper frothy stopper. It is rather uniformly cylindrical, 15-17 cm. long, the egg-mass making about 5.3 cm. of its length. It is thus too long, compared with that of *Locusta* (58-75 mm., UVAROV, 1928), *Schistocerca* (about 68 mm., BALLARD, 1932) and *Anacridium* (9-10 cm., FEDOROV, 1927). It extends nearly vertical into the soil, with a slight curving backwards, though obstacles often alter its shape.

However densely the eggs lie in an egg-pod, each one is always coated with a thin film of the secretion, this being soft and silvery at first but hardens up later on and becomes dark brown in colour.

a. *Shape and structure of the egg*

Typically, the freshly laid egg is bright yellow in colour, shaped nearly like an elongate slightly bent cylinder tapering towards both ends which are round (Fig. 1). At the posterior end of the egg lies the micropylar apparatus. This consists of funnel-shaped cuticular canals, arranged in a ring at about 0.39 mm. from the

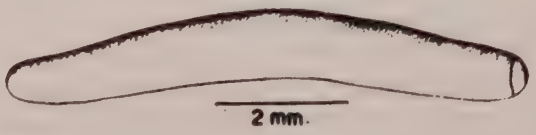

FIG. 1 : The egg.

pole. They count about 45-50 canals, while in *Locusta* they are about 35-43 (ROONWALL, 1936). In length, each canal measures 0.066 — 0.098 mm. Their outer openings are 0.026-0.040 mm. in width and they nearly touch one another, but their narrow

inner ends are separated by as much as 0.074 mm. The egg measures on an average 8.5 mm. long (as a straight line between both poles) and 1.1 mm. wide (as the greatest diameter).

b *Number of eggs in a pod*

The absolute number of eggs in a pod varies between 23 and 108 eggs with an average of 66.9 eggs. More often, however, the pod contains 60-80 eggs. In the successive layings of a female the average number of eggs in each pod is : 1st. pod = 58.0 eggs; 2nd. pod = 74.7 eggs; 3rd. pod = 70.8 eggs; 4th. pod = 61.4 eggs; 5th. pod = 57.5 eggs; 6th. pod = 63.0 eggs; and 7th. pod = 77.3 eggs.

The 8th. and 9th. layings were recorded only once and they contained 70 and 56 eggs respectively.

2. The incubation period

In field cages oviposition starts late in April and continues until early in December (according to whether the season is late or early). The incubation period in these cages (Table I) depends upon the time of oviposition.

TABLE I

The incubation period in field cages

Month of oviposition	Incubation period (in days)		
	Minimum	Maximum	Average
April	51	59	53.3
May	43	54	48.0
June	36	42	38.7
July	35	39	37.3
August	37	66	50.8
September	52	81	61.1

From these data it appears that the incubation period in nature is controlled by the prevailing temperature. The shortest period is 35 days passed by eggs laid in July when the mean maximum temperature was 37°C. in the shade. As the temperature declines during the following months, this period gradual y increases to reach 81 days in eggs laid in September and hatched late in November and early in December. Eggs laid in late September generally remain dormant till the following spring. Such period of dormancy seems to be of paramount importance to the survival of this species, since it coincides with the severe winter conditions. This period is not a true diapause, but a mere dormancy due to unfavourable conditions of temperature, and it is not necessarily passed with under artificial favourable conditions (ANDREWARTHA, 1943).

The incubation period was also studied under controlled temperature (Table II).

TABLE II

The incubation period under controlled temperatures

Temperature in °C.	Incubation period (in days)		
	Minimum	Maximum	Average
28	40	49	44.0
30	35	38	36.4
32	32	34	33.1
35	27	32	28.8
40	22	24	23.2

Studying these results, taking into consideration that humidity effect is eliminated, it will appear that high temperature considerably accelerates the egg development of *Acrida*. The shortest period is 22 days at 40°C. As the temperature decreases the incubation period becomes longer.

As regards the role of humidity, it is well known that locust eggs either shrivel up or die in dry soil; or, in a suitable degree of dryness, their development may be suspended for a very long time and made to restart on the addition of a suitable amount of moisture to the soil. To test the humidity effect on the egg development, some pods were incubated normally at 35°C. for a week. Then they were removed from the soil, and the eggs were detached from them and arranged in lots. Some lots were put in dishes floored by moistened filter paper, and so the eggs were in constant contact with water. The other lots were placed in other dishes with dry filter paper and were introduced into desiccators provided with water to produce a 100% humid atmosphere. In this latter case no water was in direct contact with the eggs which all shrivelled up and died. Eggs in contact with water developed and hatched normally. This may show that it is essential for *Acrida* eggs, in at least the early stages of their development, to be in contact with the particles of water which they fail to absorb from a humid atmosphere.

3. Hatching

a. *The hatching mechanism*

The intimate process of hatching was studied by using the same demonstrative cage used for oviposition. It was also studied by isolating eggs from their pods and arranging them in dishes provided with moistened filter paper (Fig. 2).

When ready to hatch, the embryo moves inside the egg-shell. By continual muscular wrigglings and the swelling of its several parts, especially about the head, the embryo splits the egg-shell in the region of the head and prothorax, and starts

to free itself from it. Although no regular succession of the hatching eggs in the pod was observed, the process was more pronounced in the basal region upwards.

The nascent hopper burrows its way upwards in a sinuous manner through the frothy matter of the pod. It sometimes happens that an individual penetrates the frothy coat into the surrounding sand, but it fails to go ahead and soon retreats into the pod to follow a path within the latter. After about 3 hours and 40 minutes since the embryos began to move, numerous individuals began to reach the upper

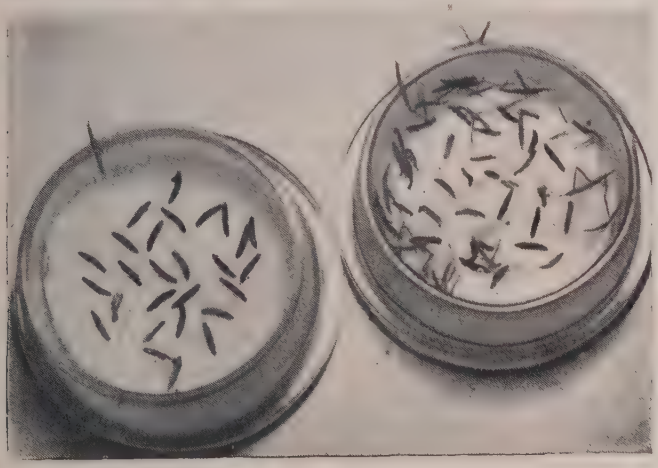

FIG. 2: Eggs hatching.

end of the egg-mass. These individuals aggregate in a cluster and move through the stopper much more rapidly than through the egg-mass. A distance as long as the egg-mass (about 5 cm.) was crossed within 27 minutes. Insects in the cluster were held together by their bodies being pressed against each other and their hind legs pressed against the wall of the hole. Individuals which were retarded in the egg-mass ascend singly along the wide path already made by the cluster and soon join the latter.

Reaching the upper end of the stopper, the cluster hesitates for a while; then, by the simultaneous cooperative pressure, they push off its button and an exit hole is forced open. Consequently the insects are thrown on one another around the orifice just made. Since the moment the embryos began to move inside the shells till the issue of the cluster, the process lasted 4 hours and 40 minutes. After the issue of the cluster single individuals get out, yet normally these are very few in number.

b. *The intermediate moult*

An individual which has just emerged from the egg does not look like the ordinary Acridid hopper. Indeed, it scarcely differs in its general appearance from the fully developed embryo in the egg. The head is somewhat bent downward, its

antennae and legs lie close to the body, and the whole insect is enclosed in a transparent membrane with separate "sleeves" for the appendages. Owing to the presence of this membrane the insect is unable to make efficient use of its appendages.

Reaching the soil surface the insect starts to shed off this membrane. Peristaltic movements appear along its body and soon the membrane is split along the dorsum of the head and thorax. By continual wriggling the membrane gradually shrivels posteriorly till at last it collects on the abdominal apex and still enclosing the distal parts of the hind legs. Then the insect stands steady on its fore and mid legs and pulls the hind legs off their "sleeves". The membrane, still adhering to the long suranal plate, is got rid of by friction with the soil. Now the insect becomes a normal nymph and, feeling free, hops away leaving the white pellicle near the pit.

Morse (1920) and others consider the membrane shed directly after hatching to be the amnion, and that this shedding is the final stage of the hatching process. However, the fact that the pellicle is non-cellular, chitinous and envelops each appendage separately is against this view, and it is therefore a true larval skin (Carothers, 1923). According to Wheeler (1893), the embryo of *Conocephalus* (*Xiphidium*) is evaginated from its amnion at the time of its final revolution. Soon afterwards, when the residual yolk has been taken into the mesenteron, a chitinous cuticle is formed over the entire body. This cuticle is shed in the egg, and the one shed after hatching is the second larval cuticle.

La Baume (1918) proposed to call the shedding of the skin after hatching "the embryonic moult" because the insect before it still resembles the embryo in appearance. Uvarov (1928), though agreeing with La Baume, regards it to be inconvenient from the practical point of view, since it would involve an alteration in the total number of moults and stages. Therefore, he proposed to neglect the first larva in the general count of the stages, and to call it the "vermiform larva", and the shedding of its skin the "intermediate moult".

c. *The hatching period*

The eggs in a given pod may all hatch in one day, or the hatching period may extend for several days with a pause of 1-7 days. A nearly similar period (1-6 days) was reported for *Schistocerca* in Egypt (Ballard, 1932). More often the whole complement of eggs hatch together in one lot. Even in the case where hatching took place in more than one day, the majority hatched on the first day. Out of 104 egg-pods, 84 pods hatched each in one lot, 6 pods in three lots, and the rest hatched each in two lots.

Mistikawy (1936), working on *Schistocerca gregaria*, regards the few nymphs remaining after the hatching of the first lot to be those at the bottom of the hole. This statement, however, does not hold true with *Acrida*, since our observations have shown that the hatching process was more pronounced in the basal region of the pod. Moreover, the retarded eggs remained with their embryos quiet in their

intact shells. Also in many of these eggs the embryonic development was clearly not completed at the time of the first hatching.

d. *Percentage of eggs hatching*

In many cases all the eggs in a pod may hatch, but it frequently happens that some of the eggs do not hatch at all. In 51 out of 104 pods (i.e. 49%) all the eggs in each pod hatched. In 15 out of the 53 remaining pods (i.e. 28.3%) all eggs but one hatched. In each of another 6 pods (i.e. 11.3%) two eggs remained unhatched In the remaining 32 pods the non-hatched eggs were more, sometimes making about 40% of the pod. The total average percentage of hatching in these 53 pods is 87.8% which is nearly similar to that recorded for *Schistocerca* (83.5%) in Egypt (BALLARD, 1932). It may, however, be mentioned that eggs subject to excessive moisture or to dryness failed to hatched.

III. THE NYMPHAL STAGE

1. Habits of the young

a. *Activity*

The young possess remarkably active powers from the moment they leave the egg. The vermiform larva reaches the soil surface by wriggling movements. It then casts off its skin and becomes able to move freely in different ways, the simplest of which being crawling. The process of crawling is manifested in numerous ways in which the legs form different coordinating groups.

A slight modification of crawling is the climbing of plants. Besides their ability to climb plants and other vertical rough objects, *Acrida* hoppers, especially the first and second instars, are able to climb vertical glass walls. This ability, however, decreases with progressive age.

The best known method of movement in Acrididae in general is jumping or hopping. An undisturbed nymph moves generally by crawling accompanied by few jumps. When disturbed, the hopper moves more swiftly by jumping, the spring being caused by a forcible extension of the hind tibiae.

In general, the hoppers' activity is greatly influenced by the temperature. In cold weather the hoppers are sluggish and move by slow crawling or, when disturbed, by feeble hops. At high temperature, on the other hand, excited movements are observed.

Acrida, nymphs and adults, are phytophilous insects, normally roosting on the vegetation where they are easily overlooked. The hoppers go from branch to another by suitable jumps, and they do not normally descend to the ground except when the vegetation is thin and when escaping a hunt.

b. *Feeding habits*

Hoppers of *Acrida*, as do other Acridids (FRY, 1927), do not feed the first

day they hatch out. Starting to feed, they select the younger leaves and begin to take light meals, but they gradually become more voracious as they advance in age.

Standing to feed, the insect may take a steady position, or may stand in an oblique or even an inverted manner with the head hanging downward. It rests with its longitudinal axis parallel with the edge of the leaf. The head is then lowered till the labrum touches the leaf, and the palpi are brought to bear lightly on it in rapid succession. Finally the insect closes its mandibles on the edge of the blade and starts to feed. During feeding the fore legs are used for grasping and manipulating the grass.

Feeding is greatly affected by temperature and humidity. Under warm conditions feeding is fairly intense, whereas a drop in temperature causes a noticeable reduction in the quantity of food consumed. Also the insect is more voracious under drier conditions than when the humidity is quite high.

It is also noticed that the hopper stops feeding shortly before moulting and for some time after the process is completed. VALOVA (1924) states that the complete interruption in feeding in these cases occurs gradually and returns to the normal also gradually.

c. *Cannibalism*

Besides feeding on plant food, *Acrida*, as do other Acridids, feed on animal food. Hoppers and adults often devour the shed skin and the dead bodies of their fellows, yet there is also much cannibalism, and an individual may attack a perfectly healthy fellow and starts to bite it.

Cannibalism is more pronounced in cases of overcrowding, in cages with mixed instars, and when the food is unfavourable. Even when the food is favourable, cannibalism also occurs, and it is not infrequent that an individual may attack another during the process of moulting and whenever it is wounded.

2. The life of the young

a. *The number of nymphal instars*

Most of the Acridid species which have been studied pass through five nymphal stages, excepting the vermiform stage. However, this is not a general rule and exceptions were recorded by many authors. Thus in *Dociostaurus kraussi* the males pass through four stages and the females through five (PLOTNIKOV, 1926). DOVNAR-ZAPOLSKY (1926) also records six stages in *Pezotettix giornae*.

In *Acrida*, the stages were found to vary with the sex, this latter being easily recognised since the first instar. The number of stages more frequently passed by the male is six and by the female is seven. A similar condition was recorded by COLEMAN (1911) in *Hieroglyphus benian*. It was not infrequent, however, for both sexes to show an additional moult, a condition which was more frequent among males. An average of 43% of the males passed through seven stages and 28.4% of the females passed through eight.

b. *Duration of the nymphal stages*

Table III shows the average duration of the stages in field cages during the different months of the year.

TABLE III

Average duration of nymphal stages in field cages

Month of hatching	Average duration of stages (in days)								Total
	1st.	2nd.	3rd.	4th.	5th.	6th.	7th.	8th.	
May	10.7	13.9	7.7	7.5	9.2	9.7	11.6	10.2	80.5
June	10.3	7.6	7.0	8.1	7.4	10.7	9.0	9.8	69.9
July	8.0	6.7	7.1	5.5	8.1	10.0	11.1	13.4	69.9
August	8.2	7.3	7.6	8.4	8.4	10.8	12.4	13.9	77.0
September	10.0	10.3	9.9	10.7	11.5	12.7	12.8	14.6	92.5
October	12.1	12.2	11.4	16.5	18.0	—	—	—	—
November	14.6	17.0	23.7	—	—	—	—	—	—

From these data it would appear that the shortest nymphal life is passed by hoppers hatching during June and July. The majority of hoppers that hatch during September reach the adult stage late in November and early in December. The rest of them, together with those hatching during October and November do not reach such stage in the same season. When cold weather prevails, a large proportion of them perishes, and only few strugglers pass the winter in a "nymphal diapause".

In the insectary the span of each stage is relatively longer than in the field (Table IV).

TABLE IV

Average duration of stages in the insectary

Month of hatching	Average duration of stages (in days)								Total
	1st.	2nd.	3rd.	4th.	5th.	6th.	7th.	8th.	
May	14.2	12.1	13.1	14.1	14.3	15.8	15.3	20.2	119.1
June	12.0	8.8	10.9	10.4	13.4	16.4	23.6	26.6	122.0
July	10.0	11.5	11.3	17.4	17.0	23.6	24.2	28.0	143.0
August	12.1	12.3	11.8	15.9	18.1	25.5	—	—	—

The shortest nymphal life in the insectary is passed by hoppers hatching early in May. They are soon overcome by the hot summer weather that accelerates their development. Those hatching later on (in June and July) will encounter lower temperature conditions and therefore their life is longer. Majority of hoppers hatching in late July and in August do not reach the adult stage and pass the winter as such with a great loss in number.

The duration of stages was also studied under controlled conditions :

aa. *Under constant temperature and fluctuating humidity*

This work was carried out at both 30 and 35°C., with the humidity freely fluctuating between 40 and 85% (Table V).

TABLE V

Average duration of stages under constant temperature (R.H. 40-85%)

Temperature in °C	Average duration of stages (in days)								Total
	1st.	2nd.	3rd.	4th.	5th.	6th.	7th.	8th.	
30	10.5	9.3	11.1	10.2	12.6	11 6	11.9	13.1	90.3
35	7.5	6.8	7.8	8.1	8.8	9.7	10.6	11.1	70.4

bb. *Under constant temperature and controlled humidity*

In these experiments three humidities (30, 70, and 90%) were used at both 30 and 35°C. (Table VI).

TABLE VI

Average duration of stages under constant temperature and controlled humidity

Temp. in °C.	Percentage R. H.	Average duration of stages (in days)								Total
		1st.	2nd.	3rd.	4th.	5th.	6th.	7th.	8th.	
30	30	12.5	10.5	10.3	11.6	12.1	13.4	13.8	13.7	97.9
	70	10.6	7.6	9.0	9.6	11.2	11.7	12.0	12.6	84.3
	90	8.8	7.9	7.2	7.5	9.1	10.6	11.8	12.2	75.1
35	30	12.0	9.5	9.0	8.8	9.9	9.5	10.8	13.0	82.5
	70	7.1	6.9	6.6	7.2	8.4	7.8	10.2	12.6	66.8
	90	7.0	6.4	7.5	7.3	7.7	7.4	10.0	10.5	63.8

From the above data it seems that the temperature has a remarkable influence on the duration of stages, these latter being shortened at higher temperatures. Humidity seems also to play a pronounced role, since higher humidities (70 - 90%) accelerate the nymphal development. Parallel results were obtained (HAMILTON, 1936) for *Locusta* hoppers in which case the favourable humidity ranges between 50-75%.

c. *The sex-ratio*

The sexes of *Acrida* hoppers can easily be differentiated in as early as the first instar. Therefore, the sex ratio of hoppers hatching from a pod was studied by simply counting the individuals of both sexes raised from isolated pods. The total

count of the offspring of 52 pods was 1660 males and 1492 females. So the males made an average of 52.6% of the offspring and the females 47.4%. In single pods the sex ratio may be 1:1, though one sex may sometimes outnumber the other. The deviation from the 1:1 ratio is generally slight, yet in few cases it is exceptionally large with the general preponderance of males.

d. *Coloration of hoppers*

Immediately after the intermediate moult, the hopper is yellowish. This colour deepens gradually into straw-yellow or brownish, or more often changes into green. After each moult the hopper is whitish, and the reappearance of colour occurs gradually, and the time taken in this process is much longer at low temperatures than at higher ones. Also humidity plays a pronounced role in the type and intensity of the colours. Thus, under dry conditions nearly all the hoppers are yellowish-white and few are pale green. Under conditions of almost saturation, on the other hand, deep green coloration prevails.

On moulting, the hopper does not necessarily give a similarly coloured elder one, but it may acquire a new colour after moulting. However, some individuals may keep on the same colour throughout their development. It is also interesting to state that a yellowish or brownish ultimate hopper does not necessarily give a similarly coloured adult, while a straw-yellow adult is raised only from a similarly coloured nymph. The ratio of hoppers from one pod acquiring the various colours of the species is absolutely variable and does not follow any regular scheme.

3. The nymphal development

The first instar

After the intermediate moult the nascent insect is yellowish with a characteristically longitudinal dark stripe on either side. Its average length is 14.7 mm. from the tip of the fastigium to the tip of the epiproct, and its head is 3.7 mm. between. the fronto-clypeal suture and the apex of the fastigium. The antenna is 3.5 mm long and is composed of 8 segments. The eyes are bright orange each with a dark longitudinal band.

The pronotal disc is slightly emarginate posteriorly and measures about 1 mm. across the middle line. The hind femur and tibia each is 4.2 mm. long. The hind tibia is characteristically black distally. The wing rudiments are hardly detected.

The abdominal sterna are nine in both sexes. In the male the ninth sternum carries posteriorly an unpaired plate which develops later on into the subgenital plate. In the female each of the eighth and ninth sterna carries a pair of rudiments which will form the ovipositor valves. The epiproct measures 1.9 mm. and is crossed near its base by a transverse suture. The paraprocts are well developed, and the tympanal depressions are absent.

The second instar

The lateral dark stripes nearly disappear, and the hind tibiae lose their apical dark colour. The average length of the body is 19.1 mm., the head 4.5 mm. and the antenna 4.7 mm. The antennal segments count 14, the third and fourth being incompletely separated. The eyes possess two bands each.

The pronotal disc is emarginate posteriorly and measures 1.7 mm. On the hind angles of the meso- and metaterga appear some rugosities; in some cases the wing rudiments are separated from the terga by a bow-shaped line. The hind femur measures 8.4 mm.

The rudiments of the ovipositor valves and that of the male subgenital plate are developed. The epiproct measures 3.2 mm. Tympanal depressions are absent.

The third instar

The average body length is 30.9 mm., the head 6.1 mm., and the antenna 7.0 mm. The antennal segments also count 14 but are now more sharply defined and all segments are completely separated. Each eye possesses three bands.

The pronotal disc is emarginate posteriorly and measures 2.3 mm. The wing rudiments are more distinct, roughly triangular in outline. The valve rudiments are more developed, the anterior pair extending below the ninth sternum which is now relatively depressed. The epiproct measures 4.8 mm., and the tympana are absent.

The fourth instar

The average length of the body is 35 mm., the head 7.5 mm. and the antenna 9.0 mm. Antennal segments are 16, with the 3rd. and 4th. segments incompletely separated. Each eye is crossed by four bands. The pronotal disc is still emarginate posteriorly, and the wing rudiments are slightly larger with more distinct venation.

The valve rudiments are more developed and the 9th sternum is much reduced. A small posteriorly pointing digitate lobe is cut off mesally from each posterior rudiment. These lobes will form the mesal valves. In the male the subgenital plate is more tapering posteriorly, with the suture separating it from the 9th. sternum obliterated mesally. The tympana are absent, and the epiproct is 6.1 mm. long.

The fifth instar

In this stage the general coloration begins to present special characters so near to the pattern of the adult. The average length of the body is 48.5 mm., the head 10 mm. and the antenna 12.8 mm. The antenna is 17-segmented, with the 3rd. and 4th. segments in the male and 3rd., 4th. and 5th. in the female incompletely separated. The eye bands are now five.

The pronotum measures 5.0 mm., the hind femur 19.6 mm. and the epiproct 8.7 mm. In the female the pronotum is still emarginate, the wing and valve rudiments are more developed, with the 9th. sternum much more reduced.

The male hoppers have certain developmental variations due to the fact that males may pass through 6 or 7 nymphal stages. The 5th. instar may therefore be the penultimate stage in which case the pronotal disc is nearly truncate posteriorly with a small median outgrowth. The wing pads are folded up, with the wings largely covering the tegmina, both pairs extending to approach the posterior edge of the metathorax. In case where males pass through 7 stages, the 5th. instar is relatively similar to that described for the female. In both cases, however, the subgenital plate is more tapering posteriorly, with its surface more convex. The tympanal depression is still absent but a membranous area appears in its position.

The sixth instar

For the male this is the ultimate or penultimate stage, and for the female it is the penultimate stage or a stage earlier. In the penultimate stage of either sex the pronotum and wing pads are similar to those described for the 5th. instar.

In the male ultimate stage, the pronotal disc has a distinct posterior process, the wing pads extend to cover about half of the 3rd. abdominal tergum, and the tympanal area is slightly depressed.

Prior to the penultimate stage, the female has its wing rudiments similar to those of the respective male hopper. The 8th. abdominal sternum acquires a small median outgrowth posteriorly. The mesal valve rudiments are more defined, and all valves are more attenuated posteriorly. In the female penultimate stage the 9th. sternum is much reduced and the bases of the dorsal valves are shifted anteriorly. The antenna is 18- segmented with the 3rd., 4th. and 5th. segments incompletely separated.

The seventh instar

This may be the ultimate stage of the male and the penultimate of the female, and both are previously described. The female may also be in the ultimate stage where the pronotum and wing pads are relatively similar to those of the ultimate male hopper. The 9th. sternum is invisible, and traces of sutures appear on the ventral valves separating their future sclerites.

The average dimentions of the ultimate male and female hoppers are :

	Male	Female
Total length	52.7 mm.	78.7 mm.
Length of the head	11.1 mm.	16.3 mm.
Length of the antenna	14.8 mm.	21.1 mm.
Length of the pronotum	6.9 mm.	10.9 mm.
Length of the hind femur.....	23.7 mm.	34.5 mm.
Length of the epiproct	8.9 mm.	10.9 mm.

IV. THE TOTAL DURATION OF THE LIFE-CYCLE

In field cages the duration of the life cycle varies according to the season. Eggs laid in April pass an incubation period of about 53 days. The young hatch in June and reach the adult stage after about 60 days. The adults become sexually mature and lay their eggs after about 13 days. So the total duration of the cycle is about 126 days.

Eggs laid in late autumn pass a much longer incubation period (about 195 days) and hatch the following April. The young reach the adult stage in about 68 days and, after about 12 days, the first pod is laid. Thus the total duration of the cycle is about 275 days.

Eggs laid in late summer and early autumn hatch after about 48 days. Some of the young reach the adult stage and the majority overwinter as such. The overwintering adults oviposit in April, and the nymphs reach the adult stage late in April and oviposit in May. Thus the total duration of the cycle is about 268 days.

Under controlled conditions (35°C., 40-85% R.H.) the duration from egg to egg is about 93 days. About 28 days are passed as eggs, 58 days as nymphs and 7 days before oviposition.

V. NUMBER OF ANNUAL GENERATIONS

In field cages, eggs laid on 9th. April hatched on 6th. June. A female reached the adult stage on 26th. July., and oviposited on 8th. August. These eggs hatched on 24th. September, some of the young reached the adult stage but the majority overwintered as nymphs. The first pod was laid on 3rd. May of the following year. So about 13 months were exhausted in two generations. In case of *Schistocerca gregaria* it was able to produce three generations per year in Egypt (Ballard, 1932). At 35°C. the duration of the cycle is about 3 months, and so it is possible to rear 3-4 generations per year.

VI. SUMMARY

1. — The egg-pod is 15-17 cm. in length and the stopper reaches nearly to the soil surface. After oviposition the female covers the orifice of the pit.

2. — The average incubation period at 40°C. is 23.2 days. By decreasing the temperature this average rises to 44 days at 28°C. Eggs laid in late autumn remain dormant till next spring. This is not a true diapause but a mere dormancy due to unfavourable conditions. When all conditions are favourable, eggs do not survive except when in direct contact with water.

3. — The outstanding feature of all nymphal instars is the elongate epiproct. The development of hoppers towards the adult stage consists in the growth connected

with the periodic moults. Males generally pass through six stages and females through seven. Each sex may acquire an additional moult, the ratio of extra moults being higher among males (43%) than females (28.4%).

4. — The duration of stages increases with decreasing temperature. A less prominent role is played by humidity, and the stages are longer under drier conditions.

5. — A pronounced effect seems to be brought about by humidity on the coloration of hoppers. Under dry conditions the colour is whitish or pale green. When humidity is sufficiently high, intense green colour prevails.

6. — Sexes of the hoppers are easily differentiated since the first instar. The sex ratio of hoppers raised from one pod is nearly 1:1, but the males more often outnumber the females.

7. — It is possible to rear about two generations per year in field cages. Under controlled conditions (35°C., 40-85% R.H.) 3-4 generations are possible every year.

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HISTOPATHOLOGICAL DESTRUCTION CAUSED TO THE COTTON LEAFWORM, *PRODENIA LITURA* F., BY SOME OF THE NEWER INSECTICIDES

[*Lepidoptera : Noctuidae*]

(with 51 Text-Figures)

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I. INTRODUCTION

The cotton leafworm, *Prodenia litura* F., is one of the most serious cotton pests in Egypt, causing the country a loss of several million pounds annually. Other than cotton, the insect feeds on a great variety of plants to which it causes a considerable damage. A complete host list of this worm is given by BISHARA (1934) and WILLCOCKS et al (1937). According to these authors, the worm was introduced to Egypt during the later part of the nineteenth century (about 1870). The favourable agricultural developments combined with favourable meteorological conditions helped the insect to be a well established serious pest.

Since the establishment of the worm in this country, many investigators worked on its biology and control (ADAIR, 1909). Among the more recent of these studies are those of BISHARA (1934) and WILLCOCKS (1937).

Prodenia litura F. has been recorded from many countries of the old world, particularly the sub-tropical and tropical zones, where the temperature does not usually fall below 10°C. (about 50° :F.). It is not recorded from Europe or America. However, several related species belonging to the same genus, are important agricultural pests in the U.S. America and South America.

Methods of control of the worm in Egypt comprise the physical, biological, legislative and chemical means. The insufficient success achieved by the legal, physical, and biological measures of control called for the necessity of combating this pest chemically. In Egypt, the use of chemical insecticides for the control of insects remained for quite a while limited due to the fear of being misused by farmers. Chemical control of the cotton leafworm thus started only about 1925 and has developed considerably more recently. Several of the newer efficient insecticides have been tried for this purpose. Since preference between such chemicals should be based on a sound scientific basis, it was found necessary to compare the efficiency of these materials common on the market. The histopathological destruction caused by such insecticides to the different body tissues of the worm have been studied here. The degree of success of various chemicals in this respect, depends upon the rate with which they act as well as the mode, site and extent of their action.

For comparing the effectiveness of various chemicals as insecticides such points should, therefore, be investigated. Studies were thus carried on here for the purpose of revealing the differences in mode, site and extent of action of some of the newer insecticides applied in the present experiments, as indicated by their histopathological effect.

II. REVIEW OF LITERATURE

The subject of chemical control of insect pests has recently been receiving much of the attention of economic entomologists all over the world. At the present time Egypt also has been using insecticides for the control of many insects and particularly the cotton leafworm, *Prodenia litura* F.

Death of an insect by a poison is usually known to be due to the alteration or malfunctioning of some physiological or metabolic processes in addition to anatomical effects resulting from the direct toxic action on the cells (STEINHAUS, 1949).

The histopathological changes caused to some poisoned insects have been studied in few cases. As a result of these studies it was found that each group of poisons usually elicits its own particular pattern of pathological changes. The pathological effect caused to the insect by a poison may be readily noticed in the gross appearance of the insect and its organs, or it may be confined to disarrangement or destruction of cellular elements. The digestive, circulatory, nervous and muscular systems as well as the fat tissue are the ones that are mainly affected by poisoning.

Histological investigations to determine the effect of insecticides have received comparatively little attention, as judged from the scanty literature on the subject.

Pilat (1935a) reported on the action of several poisons on the alimentary tract of certain insects. Woke (1940) conducted extensive studies with poisons principally arsenicals or arsenic derivatives, on the southern army worm, *Prodenia eridania*. Calcium arsenate caused disorganization of the mid-gut with the epithelial layer appearing as rather solid mass.

Hartzell (1934) studied the effects of pyrethrum, applied externally, on the nervous system of grasshoppers and mealworm larvae (*Galleria mellonella*). He found lesions throughout the main parts of the central nervous system as well as marked tigrolysis in the brain and ganglia and he concluded that death was caused by destruction of the cells of the central nervous system accompanied by paralysis.

Effects of pyrethrum were also detected by Hartzel and Scudder (1942) on many parts of the body, particularly the labial glands, Malpighian tubules, alimentary canal, epithelium and fat cells.

Hartzell (1945) and Hartzell and Wexler (1946) did similar work to determine the effect of various insecticides and activators on the nerves and muscles of houseflies.

DDT was shown to cause a slight dissolution of the fiber tract and degeneration of the nuclei both in the brain and in the fused thoracic ganglia. In spite of these pronounced neurologic symptoms histological symptoms were slight.

On the other hand, Richards and Cutkomp (1945) were unable to detect any clear-cut evidence of a degeneration in the nerve cord, mid-gut, epithelium, Malpighian tubules, thoracic muscles, heart, or nephrocytes of the cockroach dying from DDT poisoning.

Witt (1947) was unable to detect any histological changes in the central nervous system of flies poisoned with DDT. However, success of DDT in affecting sensory, motor structures and insect nervous tissue in general was recorded by Chang (1951), Roeder et al (1951).

Chadbourne and Rainwater (1953) studied the histological effects of calcium arsenate, DDT and Dieldrin on larval tissue of the boll worm, *Heliothes armigera* (Hbn.). They found that the death from calcium arsenate was due to a destruction of the mid-gut epithelial lining and clumping of nuclei in the muscle tissue. Dieldrin treated insects showed degeneration in tissues of the alimentary canal (mid-gut), fat body, muscles and parts of the Malpighian tubules. No effect in the nervous system was detected by the technique employed. In case of DDT no significant histological changes especially in the nervous system were noticed.

The effect of poisons on insect blood has been investigated by few workers, mainly Pilat (1935b) and Yeager et al (1942). The former worker detected a slight destruction including desintegration of haemocytes and the production of minute cells with deeply stained compact nuclei and with very little cytoplasm, as a result

of treatment of the migratory locust, *Locusta migratoria*, with sodium arsenite and sodium silicofluoride. The latter authors recorded blood agglutination and marked hematological changes on poisoning the southern army worm, *Prodenia eridania*, with arsenicals, fluorides and mercuric chloride.They could not detect any changes on applying nicotine bentonite, rotenone, pyrethrum, nicotine peat and phenothiazine on the same insect.

From the foregoing discussion, it can be concluded that different insecticides vary widely in the type and extent of their effect on insects, varying from no apparent histological change to very well marked damage to the various tissues.

Up till now, no work has been done on the effect of insecticides on the histology of the cotton leafworm. The present work is the first attempt in this field.

III. METHODS AND TECHNIQUES

Application of insecticides

Several insecticides were tested, on insects reared in the laboratory, for their action as ovicides and larvicides as will be discussed in a separate publication. Parathion, DDT, Toxaphene, Cotton dust, Tetrax and Chlordane were used for this purpose. Liquid insecticides were sprayed using an atomizer or an ordinary hand sprayer. Powders were dusted by ordinary hand or bellows dusters. Treated insects were transferred to clean rearing boxes where they were kept under observation. General mortality experiments helped to determine the time taken by each insecticdes to cause death of the concerned stage. This made it possible to pick up the worms for histopathological studies before the mortem symptoms interfer.

Histological studies

For histological study, the treated wo ms are picked up and fixed after different intervals from the time of treatment. Destruction symptoms are mostly studied in larvae fixed just before death. Death time is approximately known from the previous experiments carried for the determination of the general mortality picture caused by each chemical as well as from the premortal behaviour of the worms.

The larvae are fixed in warm Bouin's solution (at 60 °C.) where they are left for two minutes. Elder stages are then either cut into parts or have incisions made through their body, while young larvae are left intact. Cold Bouin is then added and the material is left then for 24 hours. The material is then washed in 70% ethanol and left there until wanted. When needed for sectioning the material is rinsed in 70% alcohol and then transferred to 80% ethanol and left there for 24 hours. Dehydration and embedding then follows employing the follow ng transfers:

(1) 90% ethanol for 4 hours, (2) 95% ethanol for 2 hours, (3) 100% ethanol for 3 hours (3 changes), (4) clove oil overnight.

The oil is removed from the tissues by washing in xylene for 15 minutes and the material is passed the following steps : (1) Xylol-paraffin for 15 minutes., (2) paraffin wax for 3 hours (3 changes: 1/2, 1 and 1 1/2 hours).

The material is then embedded in paraffin wax and prepared for sectioning.

Material treated in this way showed considerable superiority to that treated with xylol instead of clove oil.

Sections are cut in 3 main directions : transverse, median (sagital) and frontal at a thickness of about 8 microns. Sections stained with the differential double stain, Delafields's haematoxylin and Eosin were found satisfactory for the purpose of the present study.

Camera lucida drawings as well as photo micrographs for various sections are prepared and presented within the text.

Blood films were prepared according to the technique described by PILAT (1935b) and YEAGER et al (1942). A drop of blood obtained by forcepulling one of the legs, is smeared on a slide, dried gently on the flame and studied. Blood films stained with Giemsa for 15 minutes gave satisfactory results during the present study. Examination of blood films was done by the oil immersion lens of a high power microscope.

IV. ON THE CHEMICALS USED DURING THIS STUDY AND THEIR GENERAL ACTION ON THE WORM

Parathion, DDT, Toxaphene, cotton-dust, Benzene-Hexachloride (B.H.C.), Tetrax and Chlordane were used here in the general experiments carried on for investigating the ovicidal and larvicidal effect. The first four of these insecticides have been used throughout this study where their histopathological effects on the worm were detected as well. The use of the other three insecticides, namely B.H.C., Tetrax and Chlordane was limited only to preliminary experiments conducted for studying their poisoning effect on the eggs and larvae of the insect in a general way.

The chemical structure and nature of the insecticides tried during the present study have been thoroughly discussed in the extensive literature on the subject.

Parathion is one of the newer compounds recommended for the control of a variety of insects. It is an ester of thiophosphoric acid (Diethyl, paranitrophenyl-thiophosphate), insoluble in kerosene and petroleum oils, alcohols, ketones, ethers and naphthonic oils. It is stable to ultraviolet light and atmosphoric oxygen and thus stable under field conditions. Parathion is produced commercially under several names. It is known as compound 3422 or Thiophos (American Cyanamid Co., U.S.A.), E 605 or Fosferno-20 (Plant Protection Ltd., London). This insecticide is applied in fairly very low concentrations ranging between 0.01 to 0.5%. At such concentrations it has clearly proved its unquestionable superiority in protecting various agricultural crops from insect attacks in different countries (GANNON et al., 1955; SOLIMAN, 1956; HARRIES et al, 1956).

DDT or Dichloro-Diphenyl-Trichloroethane, is one of the synthetic organic compounds with outstanding insecticidal properties (Wallace, 1954; Perimmer et al., 1956).

DDT is unstable under alkaline conditions or in water with certain elements such as iron which causes its decomposition. It is slightly soluble in water and is quite soluble in most oils, cyclohexanone, dioxane, chloroform, benzene and acetone. The activity of this poison is attributed to its physical association with lipids of the cuticle and internal cell membranes of the insect and that the necessary lethal action is associated with irreversable changes in structural organization. DDT breaks down easily in the presence of sunlight and alkaline compounds. It is less poisonous to human beings and other warm blooded animals than to insects; a fact which is explained in view of the physiological differences existing among both groups. It has been suggested that the presence of cholesterol, not synthesized in insects, rapidly compensates the effect of this insecticide in warm blooded animals.

Toxaphene is also a comparatively new insecticide which is a chlorinated hydrocarbon with outstanding insecticidal properties. It has been previously identified as compound 3956. It contains from 67 to 69% chlorine. Toxaphene, when pure, is a waxy solid material that melts in the range of 65 to 90 °C., and has a density of 1.6. It is very soluble in common organic solvents. Like other chlorinated hydrocarbons, toxaphene liberates H Cl upon heating or exposure to ultra-violet light, the rate depending upon temperature and amount of catalytic impurities. This insecticide is soluble in a number of organic solvents such as acetone, benzene, fuel oil, kerosene and ethyl alcohol, while it is insoluble in water. The success of toxaphene in controlling several agricultural pests has been reported upon by several authors and more recently by Fleming (1951), Fife (1954), Gannon et al. (1955).

Cotton-dust is used in Egypt as an insecticide in several formulations most commonly as a mixture containing 3% of the gamma isomer of B.H.C. 10% DDT, 40% sulphur and 47% inert ingredients. This cotton dust mixture is referred to as compound : 3/10/40. Other formulations such as 3/5/40 and 3/10/0 are also being used in certain cases.

B.H.C., which is one of the components of the cotton dust, is similar to DDT but with higher vapour pressure. It is compatible with DDT, such compatibility results in a synergism in the action of both chemicals and this is the reason which favours applying cotton dusts composed of a mixture of both B.H.C. and DDT rather than using their components independently. Sulphur is added to both in the cotton dust mixtures commonly used in Egypt to help their miticidal effect and to help also as a fungicide.

General action of he used insecticides on the worm

It is obvious that when an insect is affected by a toxic chemical agent, a pathological state occurs resulting from the destruction of its tissues, or from the interruption of certain physiological processes. The end result brought about by

a certain chemical insecticide on the insect depends on the type of tissue or system affected.

According to STEINHAUS (1949), generally the earliest symptoms on poisoned insects is the decrease of their activities but with the retention of the ability to crawl, fly and keep their equilibrium. As the effect of the poison increases, these abilities are inhibited gradually. The facility for regaining the equilibrium frequently being the first to loose. Movement of the legs then slows down considerably. With only slight movement to be detected. Other symptoms may be noted, depending upon the particular poison concerned.

During the present investigation, the following general symptoms were noticed mainly on the fifth stage larvae. Such observations are original and have not been previously recorded elsewhere.

Larvae treated with Parathion (0.1%) became considerably inactive after about 1 to 1 1/2 hours. A liquid discharge is expelled from both their mouth and anus. In such larvae apparently also an exudate is secreted through the body-wall surface.

Insect larvae treated with DDT (0.5%) became inactive in about 2 hours. After 3 hours slight convulsions started to appear becoming severe few hours later. This was then followed by prolonged period during which the worm shrinks considerably.

In case of Toxaphene the whole body of the treated worm is liquified as if it has been rotten. It takes the larva not more than 1 hour to start showing such symptoms when treated with 2% toxaphene.

Similar to those treated with DDT, larvae treated with cotton dust are considerably shrunk. In such case, however, shrinkage is much less remarkable than with DDT alone. This symptom appears in lesser time in case of cotton-dust than with DDT.

The symptoms expressed by a specific chemical are usually the same in their general nature in case of the different stages of the worm. However, their is detectable variation in the time required for the appearance of these poisoning signs. The appearance of such symptoms is faster, the younger the treated stage is.

Differences between the effects of various insecticides will be more understood after studying their histopathological symptoms as discussed later on in the text.

V. HISTOPATHOLOGICAL DESTRUCTION CAUSED BY INSECTICIDES TO BODY TISSUES OF THE WORM

(Figs. 1-5)

Some of the changes which occur to poisoned insects are known to be histopathological in nature. In such cases the injury is observable microscopically in the tissues and cells of the affected insects.

In order to grasp the changes in poisoned insects larvae the normal histology of the untreated or healthy insects at the same stage as that of treated ones usually

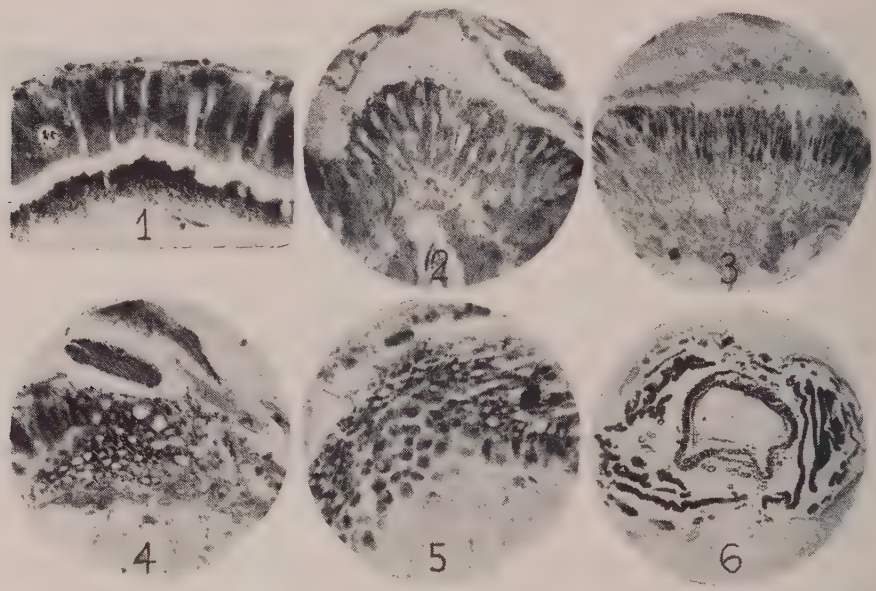

FIG. 1: Part of a transversal section in mid-gut of a healthy worm showing outer musculosa, basement membrane, epithelial layer with columnar, calyciform, and regenerative cells. — FIG. 2 : Part of transversal section in mid-gut wall of parathion treated larva showing muscular coat detached from epithelium, the latter being exfoliated from the basement membrane. The epithelial cells are elongated and vacuolized. The nuclear chromatin aggregated in lumps giving the nucleus a rough appearance. Some of these cells are torn and the peritrophic membrane destroyed. — FIG. 3 : Part of transversal section in mid-gut wall of DDT treated worm showing folding of circular muscle layer of the musculosa and its detachment from epithelium and exfoliation of the latter from the basement membrane into large sheets with cells usually keeping their normal histology. The nuclei elongated having ampullae-like appearance with granular particles within. The inner border of the epithelium is vacuolized and broken into parts. — FIG. 4 : Part of transversal section in mid-gut wall of Toxaphene treated larva showing degeneration and destruction of epithelium and its exfoliation from the basement membrane and appearance of vacuoles inbetween cells. Clumping of nuclear chromatin is also noticed. — FIG. 5 : Part of a transversal section of mid-gut wall of Cotton-dust treated worm showing epithelium detachment from musculosa and destruction of longitudinal muscle fibers of the latter are seen. Desintegration of epithelial cells and clumping of nuclear chromatin and destruction of peritrophic membrane exist. — FIG. 6 : Transversal section in the mid-gut region of a healthy third instar larva of the cotton leafworm, showing the arrangement of the various body structures.

preceded the histopathological studies at present. Such histological study has not been made before and is described here for the first time. Tissues which are found most affected by the insecticides applied here are those of the mid-gut, fat-body,

muscles, Malpighian tubules and nervous ganglia. A brief account on the normal (healthy) histology of each of these tissues in the third instar larva is here outlined in connection with descriptions of such affected tissues outlined here.

Other tissues are apparently not affected as a result of the present treatments or else show no symptoms after the period allowed before fixing the larvae.

Larvae experimented with here were taken at the middle of the stadium (third) in order to avoid confusions due to moulting. The third instar larva was preferred here because of its moderate size which facilitates both its handling as well as its histological study. Other larval stages were also examined for comparative purposes. The sixth instar larva avoided in order to keep away from confusions that might be caused due to histological changes preparatory to formation of adult tissues.

Mid-gut

A. Normal histology of the midgut of the healthy (untreated) larva

(Figs. 6 and 7)

The histological structure of the mid-intestine of the larva of the cotton leaf worm at the third instar is simple. Its wall is made up of the musculosa to the outside, it is composed of two layers of muscle fibers, the outer of longitudinal fibers and the inner of circular ones. Next to the musculosa inwards is a basement membrane which is followed by an epithelial layer of cells lining the mid-gut cavity. Within the lumen there is a thin sheet of detached material closely surrounding the food mass and known as the peritrophic membrane.

The epithelium consists of a single layer of different types of cells, typical for similar caterpillars (YUNG Tai, 1929). Of these there are three principal types; columnar, calyciform (goblet) and regenerative (interstitial) cells.

The columnar cells are cylinderical, every cell containing a large coarsely granular nucleus occupying a middle position within the cell.

The calyciform cells are shaped somewhat like a calyx and are seen in great numbers between the columnar cells; each has in its mesal part a large ampulla opening by a narrow neck through a small aperture on the inner surface. The nucleus of such a cell lies at the basal end of the cell.

The regenerative cells are small and rest on the basement membrane between the bases of the other cells. They are round or elongate and contain each a large nucleus surrounded by a small amount of strongly basophilic cytoplasm.

The epithelial cells function in the secretion of juices required for digestion, in the absorption of selected products of digestion and their transference to haemolymph. Absorption probably takes place largely, if not entirely in the mid-gut (HENSON, 1930).

The circular muscle fibers constitute the principal layer of the musculosa and is very close to the basement membrane of the pithelial cells. The longitudinal fibers, lying external to the circular ones are few and are widely spaced.

B. Histopathological action of insecticides

Effect of parathion (Fig. 8)

The changes noticed in the mid-gut region of larvae treated with parathion showed that the most profound histological changes occurred in the epithelium The muscular coat seemed to change very little. However, it is found to be detached from the epithelial layer of the gut and also a separation of its elements is encountered.

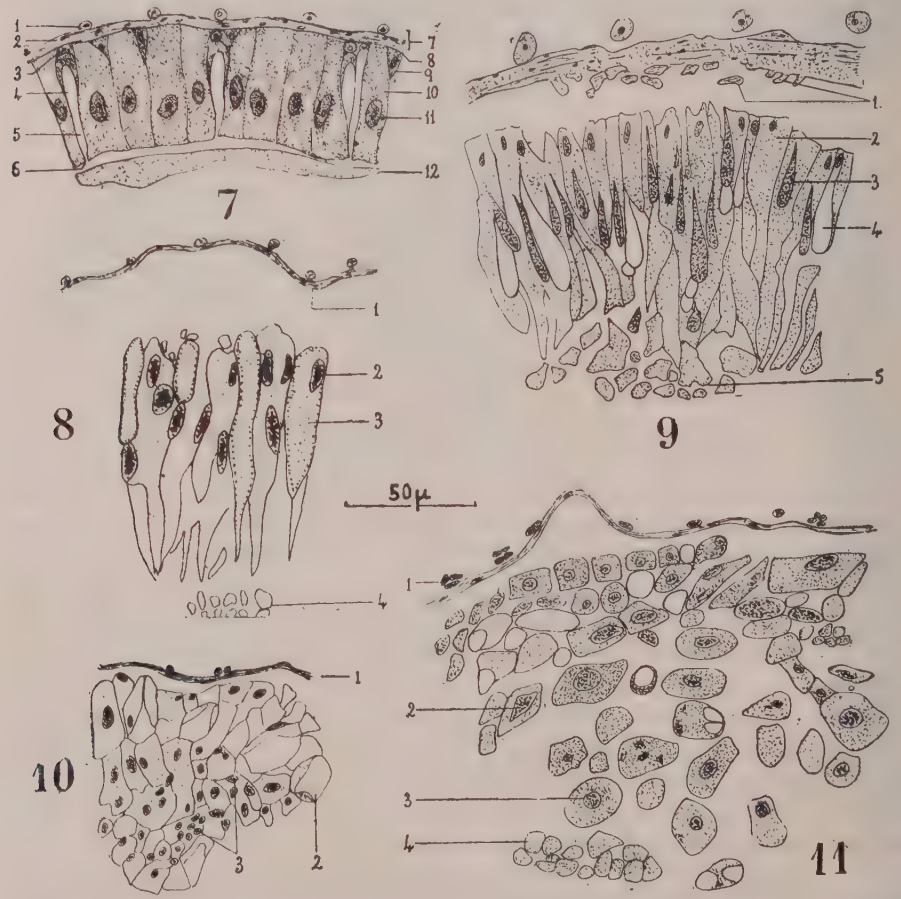

Fig. 7 : Part of a transversal section in mid-gut wall of a healthy larva : (1) longitudinal muscle layer of musculosa; (2) circular layer of musculosa; (3) nucleus of goblet cell; (4) cavity of goblet; (5) neck of goblet cell; (6) opening of goblet cell into lumen; (7) musculosa; (8) basement membrane; (9) replacement (regenerative) cell; (10) epithelial columnar cell; (11) nucleus of epithelial cell; (12) peritrophic membrane. — Fig. 8 : Part of a transversal section through mid-gut wall of Parathion treated worm : (1) musculosa detached from epithelium; (2) nucleus of epithelial cell; (3) destroyed epithelial cell; (4) torn cellular particles within lumen of gut. — Fig. 9 : Part

of a transversal section in mid-gut wall of DDT treated larva : (1) degenerated muscles; (2) columnar epithelial cell partly retaining its histological chracters; (3) elongated ampulla-like nucleus; (4) ampulla-shaped vacuole; (5) torn parts of inner border of epithelium. — FIG. 10 : Part of transversal section of mid-gut wall showing type of destruction due to Toxaphene poisoning : (1) musculosa slightly separated from epithelium; (2) vacuole; (3) nuclei with compact chromatin mass. FIG. 11 : Part of transversal section of mid-gut wall of Cotton-dust treated larva : (1) broken longitudinal fibers of musculosa; (2) chromatin of nucleus having a rough granular appearance; (3) detached and broken epithelial cells; (4) portions of epithelial cells loose within the lumen of gut.

As a result of parathion poisoning, the mid-gut epithelium is exfoliated from its basement membrane which is completely destroyed. Meanwhile, the epithelial cells are strongly vacuolated and considerably elongated. The boundary lines between the cells disappear and the nuclei are scattered in a random picture. The nuclear chromatin gathers into large irregular structure, giving the nucleus a rough granular appearance. Some of these cells are torn and exfoliated from the other epithelial cells in small particles. Also the peritrophic membrane is here destroyed.

Effect of DDT (Fig. 9)

At present DDT caused profound changes in the different larval tissues. Such results disagree with the findings of CHADBOURNE and RAINWATER (1953) who claimed that DDT failed to demonstarate any significant histological changes in any of the tissues of the boll worm, *Heliothes armigera* larvae and particularly the nervous tissue.

Both the epithelium and muscles of the mid-gut of DDT treated larvae showed clear changes. The musculosa is slightly degenerated and is detached from the epithelium but to a lesser extent than what occurs in case of parathion poisoning. In some of its parts the circular muscle layer may be disturbed and much folded.

The epithelium is exfoliated from the basement membrane in large sheets in which some of the cells retain their typical (normal) histological characters. Most of the change is confined to the nuclei of the epithelial cells. These have been considerably elongated acquiring an ampula like form with coarse-granular particles filling up all the space of the ampulla. The epithelial cells themselves are vacuolised developing ampulla-like vacuoles. From the inner ends of the epithelial cells small parts of different sizes are detached. The peritrophic membrane is here completely destroyed.

Effect of Toxaphene (Fig. 10)

Toxaphene poisoning was found to cause desintegration and destruction of the epithelium of the mid-gut of the cotton leafworm larvae at present study. This destruction is accompanied by exfoliation of the epithelial layer from the subjacent connective tissue sheath, the basement membrane. The epithelium becomes here disconnected from this underlying basement membrane layer and meanwhile it becomes broken into small portions. Vacuoles also show up between these desintegrated cells. The nuclear chromatin of the epithelial cells forms a compact mass

broken up into intensely coloured separate lumps of varied sizes. This results in a complete obliteration of the structure of these nuclei.

The muscular coat (musculosa) seems to change very little as a result of this treatment with toxaphene. It does not become detached from the epithelium, as it is the case with parathion and DDT treatments, but it remains close to it. The peritrophic membrane is destroyed and disappears completely leaving no traces traces whatsoever.

The type of destruction caused to the mid-gut by Toxaphene is somewhat similar to that reported by PILAT (1935a) on using calcium arsenate on the migratory locust, *Locusta migratoria*. This indicates that it is not necessary for the insecticide to be of the stomach poisoning type in order to express histopathological symptoms on the mid-gut. of an insect. At present. the contact poisons including toxaphene were able to cause certain malformations to the mid-gut which were identical with those resulting from using stomach poisons such as calcium arsenate when ingested by the corresponding experimental insects.

Effect of Cotton-Dust (Fig. 11)

The musculosa of the mid-intestine in larvae treated with this insecticide is greatly affected. In some regions it is detached from the epithelium but in other parts it remains intact. The longitudinal muscle fibers in this layer are considerably degenerated. These fibers loose their normal appearance and develop various fissures.

The mid-gut epithelium shows considerable desintegration and complete destruction. The cells are here separated from each other with the disappearance of the boundary lines inbetween. Small portions of the epithelial cells are separated from their inner ends, and are sloughed off into the lumen of the gut. In addition the nuclear chromatin in such cells gather into large irregular lumps, giving the nucleus a rough granular structure.

In these larvae treated with cotton-dust also the peritrophic membrane is entirely missing.

Fat-body (Figs. 12-21)

A. Normal histology (Figs. 12 and 17)

At this stage, in section the fat body is ribbon like. The fat cells are closely adherent and the external surfaces of the cell masses are covered by a delicate membranous sheath. Their cytoplasm is homogeneous, free from vacuoles or inclusions and with big nuclei. Such structure met with here is similar to what is described by several authors for the most common insects (KREUSCHER, 1922; SCHNELLE, 1923, and SNODGRASS, 1935).

Effect of Parathion (Figs. 13 and 18)

The histological changes caused by paration to the fat-body of treated larvae is the most marked destruction. In this case completed and strong vacuolization

of the fat-body cells is observed. The nuclei shrink due to the high pressure of the vacuoles exerted thereupon. This shrinkage is so considerable that such nuclei are easily overlooked and may be considered as if have completely disappeared.

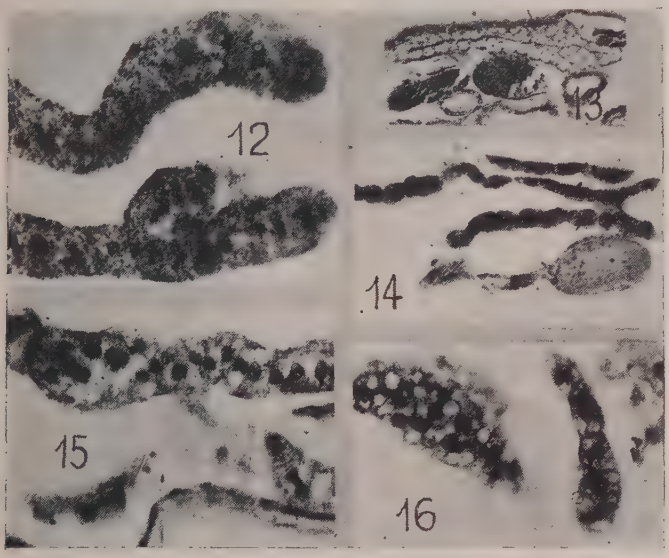

FIG. 12 : Section in fat tissue of a healthy worm : ribbon-like surrounded with delicate membranous sheath and having a homogeneous chromophillous cytoplasm free of vacuoles or inclusions and possess big nuclei. — FIG. 13 : Section through fat-body of parathion-treated worm : fat cells highly vacuolized and their nuclei shrunk and so easily overlooked. — FIG. 14 : Fat cells of DDT treated larva showing : shrinkage of cytoplasm and clumping of nuclear chromatin. — FIG. 15 : Section through fat cells of toxaphene treated worm showing : destruction of ensheathing membrane and vacuolization of cells. Cytoplasm shrinkage and nuclear degeneration are noticed. — FIG. 16 : Section in fat tissue affected by cotton-dust treatment showing : destruction of membranous sheath surrounding fat cells, clumping of nuclear chromatin and vacuolization of cells.

Effect of DDT (Figs. 14 and 19)

DDT poisoning has a considerable histopathological effect on the fat-tissue. Its cells are separated from each other and show clear shrinkage of cytoplasm. Also clumping of chromatin into rod-like or oblong dense masses is observed. These findings are similar to those reached by HARTZELL and SCUDDER (1942) in using pyrethrum on the housefly, *Musca domestica.*

In their experiments besides affecting the fat-body, pyrethrum expressed its action on the alimentary canal and Malpighian tubulus.

Effect of Toxaphene (Figs. 15 and 20)

Application of Toxaphene on the cotton leafworm larvae during the present

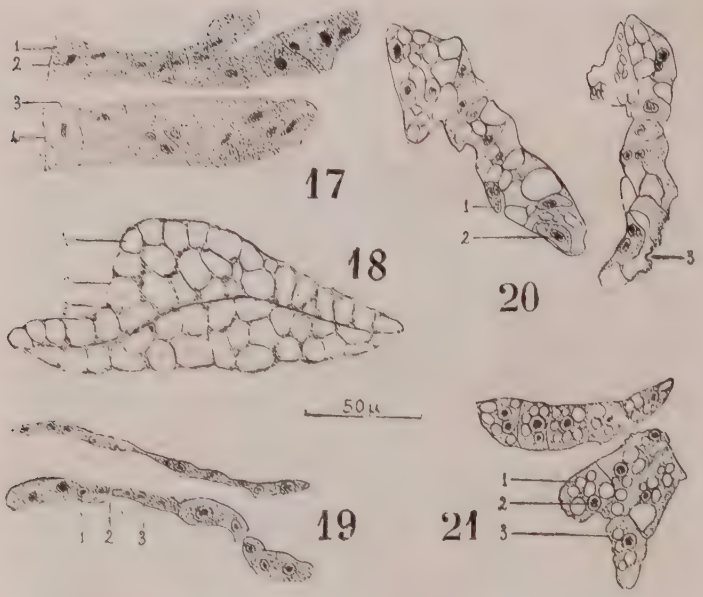

Fig. 17 : Section through fat tissue of a healthy third instar larva : (1 and 4) fat cells with cytoplasm devoid of vacuoles and inclusions; (2) nucleus of fat cell; (3) membranous sheath surrounding fat tissue. — Fig. 18 : Fat tissue of Parathion treated larva in section : (1) vacuolized fat cells; (2) membranous sheath; (3) ill-defined nucleus of fat cell pushed against cell wall. — Fig. 19 : Part of fat body tissue of DDT treated larva in section : (1) fat cell with clumped nuclear chromatin; (2) separated cells due to tearing of membranous sheath; (3) fat cell with shrunk cytoplasm. - - Fig. 20 : Fat tissue of Toxaphene poisoned larva in section : (1) fat-cell; (2) fat cell nucleus; (3) torn membranous sheath. - - Fig. 21 : Section through fat tissue of cotton dust treated worm : (1) vacuoles within cells; (2) nucleus with clumped chromatin; (3) torn membranous sheath.

study resulted in vacuolization of the fat-cells and in destruction of the membranous sheath surrounding them.

The cytoplasm of the affected fat-cells is also shrunk due to the presence of the vacuoles. The nuclei as well appear to be slightly degenerated.

Effect of Cotton dust (Figs. 16 and 21)

The membranous sheath of the fat-body is here damaged. Clumping of nuclear chromatin of the fat-cells as well as vacuolization also take place as a direct result of applying this insecticide on the worms.

The Muscles (Figs. 22-30)

A. Normal histology (Figs. 22 and 27)

As typical for insects (Wiggelsworth, 1947) the muscles are here composed of striated fibers where the striations are difficult to detect. Each fiber consists of

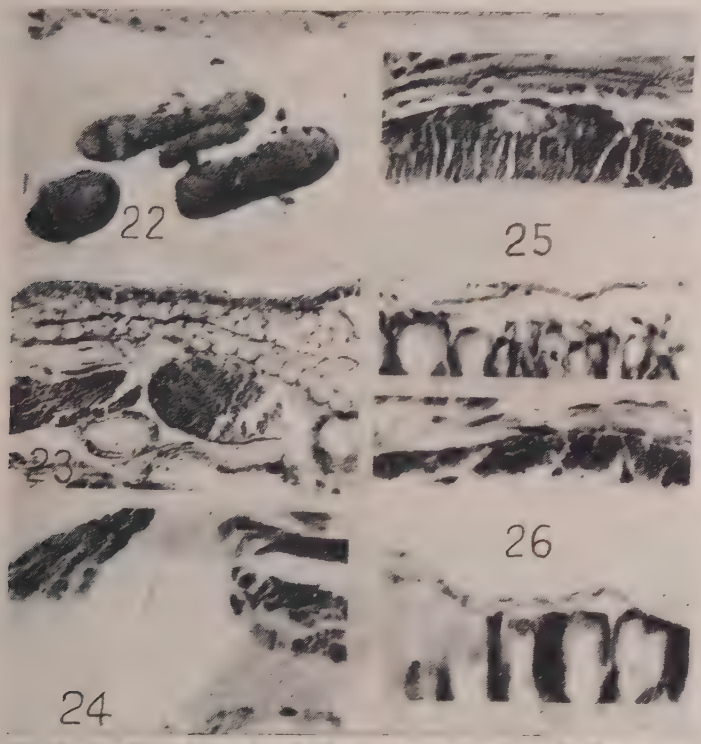

FIG. 22 : Section through muscles of a healthy worm showing : fibrillae and striations, the surrounding (ensheathing) sarcolemma underneath which lie the nuclei embedded in the sarcoplasm. — FIG. 23 : Section through muscles demonstrating the effect of Parathion : loss of both turgidity and striations and the presence of fissures, being torn into various portions. — FIG. 24 : Muscles of DDT treated worm in section : fissures apparent and sarcolemma destroyed. — FIG. 25 : Toxaphene treated muscles in section : fibers and sarcolemma considerably damaged and the bundles are broken down into parallel divisions. — FIG. 26 : Section through muscle bundle of Cotton-dust treated worm : loss of turgidity and breaking down of fibers and clumping of nuclear chromatin and tearing up of the sarcolemma.

a number of parallel fibrillae or sarcostyles, occupying the whole of the cross section of the fiber and which are laid down in a plasma or sarcoplasm. Each fiber is ensheathed in a structureless membrane, the sarcolemma. The nuclei of the sarcoplasm are disposed immediately beneath the sarcolemma.

B. Histopathological destruction in poisoned insects

Effect of Parathion (Figs. 23 and 28)

The histopathological changes caused by parathion to muscles is comparatively very little. As a result of such treatment the muscles loose their normal turgid

appearance and their striations. Fissures appear in the muscular bundles but they are not completely torn into separate parts. Small parts are however broken and show destruction of the sarcolemma. These changes are different from those noticed by HARTZELL and STRONG (1944) on the housefly, *Musca domestica*, treated with pyrethrum where fenestration of the cytoplasm and clumping of the nuclear chromatin, are only recorded.

Effect of DDT (Figs. 24 and 29)

The malformations caused by DDT to muscles range between slight degeneration, the occurrence of fissures, and the complete destruction of the whole tissue. The appearance of fissures and the breaking down of the muscles into small parts are attributed to the destruction of the sarcolemma. Such affected muscles loose their normal turgid appearance and have completely degenerated nuclei.

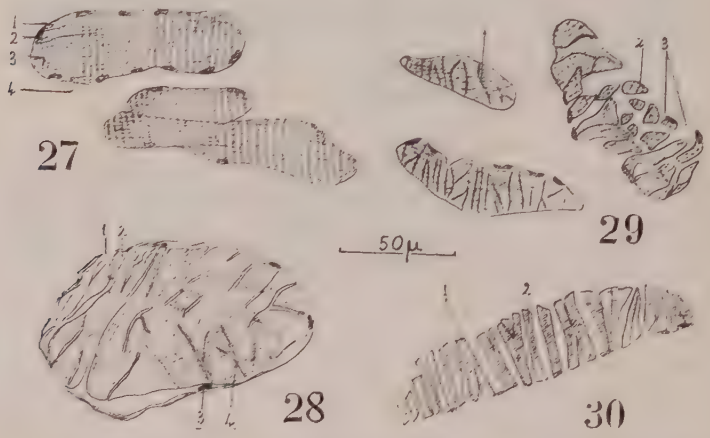

FIG. 27 : Part of body muscles of healthy worm in section : (1) light band; (2) nucleus with sarcoplasm around; (3) dark band; (4) fibrillae; (5) sarcolemma. — FIG. 28 : Section through a muscle bundle of Parathion treated larva : (1) torn sarcolemma; (2) broken muscular portions; (3) nucleus with clumped chromatin; (4) fissure within muscular tissue. — FIG. 29 : Section through muscles of DDT poisoned larva : (1) fissures within bundles; (2) broken muscle portions; (3) torn sarcolemma. — FIG. 30 : Section through muscles of Toxaphene treated worm : (1) broken parts of muscle tissue; (2) striations, within fibers, destroyed.

Effect of Toxaphene (Figs. 25 and 30)

In muscles of larvae treated with toxaphene the sarcolemma is completely destroyed and the muscle fibers are broken into several parts. The fissures dividing the muscle bundles occur in a transverse direction and never lengthwise. The division of the muscles is so regular that the divided parts are distinctly parallel to each other. The fibers show no loss of striations in spite of such considerable destruction.

Effect of Cotton-dust (Fig. 26)

In this case the sarcolemma is torn. Also vacuoles are formed within the muscle fibers of larvae treated with cotton dust. Such symptoms met with in muscles are almost similar to those found by KRUGER (1931) in larval muscles of *Corethra pluminicornis* F. poisoned with pyrethrum.

At present the muscles are seen to loose their turgid appearance. They also develop various fissures resulting in breaking out of the fibers into various parts of different sizes. These changes are also accompanied by clumping of the nuclear chromatin.

Malpighian tubules (Figs. 31-40)

A. Normal histology (Figs. 31 and 36)

Each tube is covered by a homogeneous membrane (basement membrane). Its wall is made up of few cells in one layer. Usually one cell surrounds one-half

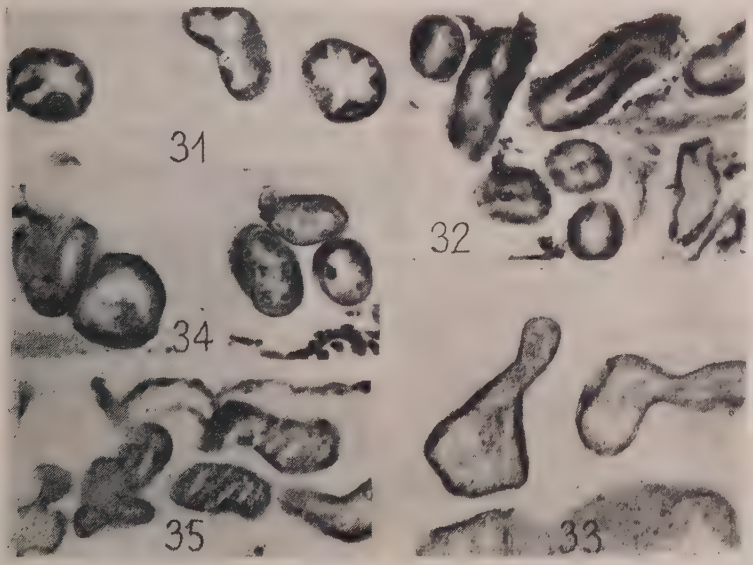

FIG. 31 : Transversal section in Malpighian tubules of healthy larva: tubules covered with a homogeneous membrane, the walls made up of few cells in one layer with the bases of the cells striated, cytoplasm pigmented. — FIG. 32 : Transversal section in Malpighian tubule of Parathion treated worm : nuclei degenerated, and with decreased lumen in which appear certain deeply stained particles. — FIG. 33 : Effect of DDT on Malpighian tubule : vacuolization of cells and degeneration of nuclei. — FIG. 34 : Transversal section of Malpighian tubule of Toxaphene treated worm : nuclear chromatin clumped leaving an outer clear area around the periphery.
FIG. 35 : Effect of Cotton-dust illustrated in a transversal section in Malpighian tubules : parallel bands of particles are spread out within the lumen blocking it, nuclear chromatin is clumped into compact intensely coloured mass.

or two-thirds of the lumen of the tubule. The base of the cells, adjacent to the basement membrane possesses a striated appearance due to the presence of vertical or radial hardly detectable striations at the basal region of their cytoplasm. The cytoplasm of the cells is filled up with pigmented droplets. There are small diverticula extending from the lumen into the cells.

B. Histopathological action of intecticides

Effect of Parathion (Figs. 32 and 37)

The histopathological destruction brought about by parathion to the Malpighian tubules are mainly expressed in a degeneration of the cell nuclei, a decrease in the lumen of the tubules with an increase in the thickness of the epithelial cells of its wall.

Small particles deeply stained with haematoxylin, similar to those noticed by Chadbourne and Rainwater (1953) upon using Dieldrin on the third instar larva of the boll worm, *Heliothes armigera* (Hbn.), appear within the lumen of the tubules.

Effect of DDT (Figs. 33 and 38)

In larvae treated with DDT the nuclei of the Malpighian tubules cells show serious degeneration accompanied with clumping of the nuclear chromatin. An increase in the lumen of the tubules takes place as a result of shrinkage of the cytoplasm of the epithelial cells forming their walls.

The epithelium shows also considerable vacuolization, degeneration or desintegration with some of the degenerated parts falling in the lumen.

It should be noticed that such effects brought about by DDT to the Malpighian tubules are quite different from those caused by parathion where in case of the latter the Malpighian tubules show a decrease in their lumen due to the extension of the epithelium inwards. In other words treatment with parathion causes the epithelial cells to increase in thickness.

Effect of Toxaphene (Figs. 34 and 39)

The Malpighian tubules here show clumping of their chromatin granules into rod-like masses leaving clear chromatin free peripheral area just inside the nuclear membrane. Such effect brought about here by toxaphene on the Malpighian tubules cells of the cotton leafworm larva is identical with what has been previously recorded by Hartzell and Scudder (1942) on the general histopathological symptoms caused to all tissue cells of the housefly, *Musca domestica*, upon treatment with pyrethrum.

In addition to its effect on the nuclei, toxaphene causes the appearance of rounded particles of different sizes in the lumen of the Malpighian tubules. The nature of such exudate should be physiologically investigated for being so far unidentified, a study planned for the future.

Effect of Cotton-dust (Figs. 35 and 40)

Larvae treated with cotton-dust show a contraction of the walls of the Malpighian tubules resulting in the collapse or complete disappearance of their lumens. In other cases the lumen of the tubules is blocked by certain particles of variable sizes arranged in bands parallel to each other. Such particles are most probably the resultants of cellular desintegration.

The effect of this poisoning is also expressed in the nuclear chromatin seen forming a continous compact mass which is intensely coloured with the present technique.

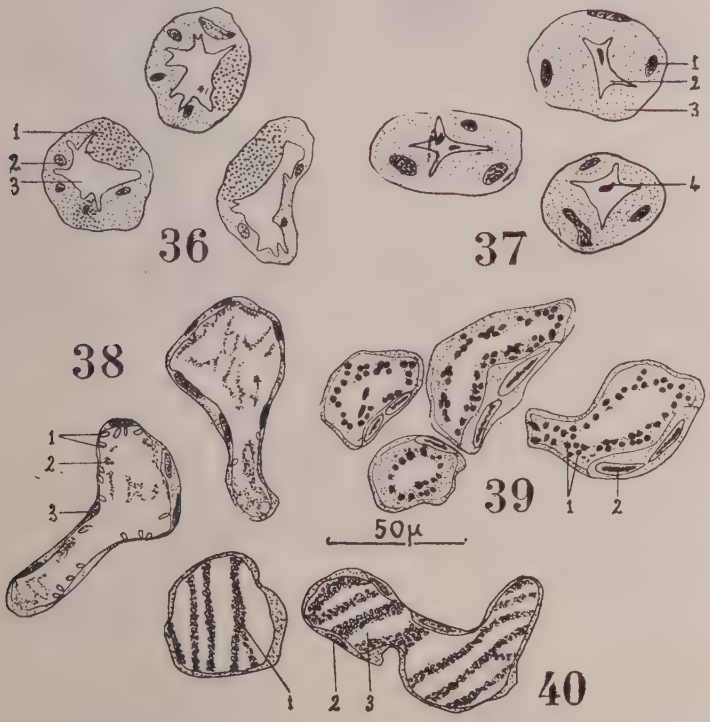

Fig. 36 : Transversal section through Malpighian tubules of a healthy worm : (1) pigmented particles; (2) nucleus of epithelial cell; (3) lumen of tubule. — Fig. 37 : Transversal section through Malpighian tubules of Parathion poisoned worm showing malformations resulting of poisoning : (1) degenerated nucleus; (2) narrow lumen of tubule; (3) cytoplasm of epithelial cell; (4) deeply stained inclusions within lumen. — Fig. 38 : Tranversal section through Malpighian tubules of larva treated with DDT : (1) vacuoles; (2) remains of degenerated epithelium; (3) nucleus with clumped chromatin. — Fig. 39 : Transversal section through Malpighian tubules of Toxaphene poisoned insect : (1) rounded particles of various sizes; (2) nucleus with rod-like chromatin mass. — Fig. 40 : Transversal section through Malpighian tubules of cotton dust treated larvae : (1) particles of various sizes arranged in parallel strands within lumen; (2) nucleus with clumped chromatin mass; (3) lumen almost blocked with particles.

Nervous tissue (Figs. 41-49)

A. Normal histology (Figs. 41 and 46)

Of the central nervous system, the ventral nerve cord ganglion is an oval mass of nerve tissue. As common for other generalised insects, as described by Zawarzin (1911-1924), the ganglion has the following structure :

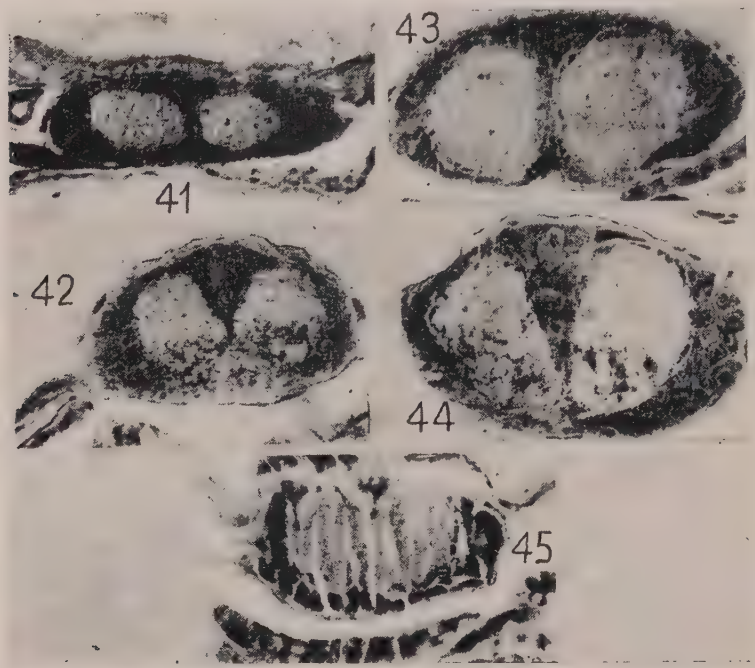

Fig. 41 : Transversal section in ventral nerve ganglion of a healthy worm : ganglion invested in a nucleated sheath, the neurilemma; the nerve fibers occupy the central region whil the nerve cells exist on the periphery. — Fig. 42 : Transversal section in nerve ganglion of Parathion treated worm : the appearance of granules around the neuropile mass. The chromatin of the nuclei of the nerve cells is clumped and some nuclei are partly degenerated. — Fig. 43 : Transversal section in ventral nerve ganglion showing effect of DDT : neuropile mass vacuolized, granules exist among the nerve cells particularly dorsally. — Fig. 44 : Toxaphene effect on nerve tissue illustrated in a transversal section in nerve ganglion : nerve cells degenerated and both cells and fibers are granulated. Destruction of the neurolimma is observed. — Fig. 45 : Transversal section through a ventral nerve ganglion of Cotton-dust treated worm : destruction of neurilemma and breaking down, vacuolization and granulation of the neuropile mass as well as chromatolysis of nerve cell nuclei are noticed.

It is invested in a nucleated sheath, the neurilemma. The principal cellular elements of the ganglion which are the nerve cell bodies are arranged in the lateral, dorsal and ventral parts. The central parts are occupied by a neuropile mass which

is the medullary substance of a dense mass of fibrous tissue forming the interior of the ganglion.

B. Histopathological destruction caused by insecticides

The microscopic changes that may occur in the nervous tissue of poisoned insects are extremely difficult in interpretation and are subject of contradiction between various authors.

HARTZELL and his co-workers (1934-1946) recorded distinct changes in the nervous tissue which they attributed to poisoning. RICHARDS and CUTKOMP (1945), on the other hand believe that the visible histopathological changes induced in nerves by insecticides are largely postmortem and hence are too complex for analysis with present informations, techniques and methods.

In spite of such differences of openion, STEINHAUS (1949) states that, regardless of the variance in views as the significance of the various histopathological changes seen in poisoned insects, it would be unwise to disregard all the reactions seen as of no value, at least when they are compared with adequate controls. He adds that one can make use of such information while at the same time realising that in looking at killed tissue one is not necessarily seeing the same things that one would be seeing were he looking at living tissues. Furthermore, he considers that such histopathological observations may be of considerable significance for diagnostic purposes that may explain very little of the physiology of tissues subjected to the toxic action of poisons. Such physiological changes in the tissues are worth studying, a work planned for the future by the present authors.

Effect of Parathion (Figs. 42 and 47)

During this study in the nerve ganglia of larvae affected by parathion, small particles and granules are seen surrounding the neuropile mass (the fibers) but no granules are obsreved inside or outside the nerve cell bodies. Clumping of the chromatin of the nuclei occurs and some of the nerve cell nuclei are degenerated and divided into parts.

Effect of DDT (Figs. 43 and 48)

At the present study the effect of DTT on the nerve ganglia is very well observed. This results in the occurrence of vacuoles having the appearance of holes within the nerve fibers. RICHARDS and CUTKOMP (1945), who noticed such structures in nerve fibers of some dead insects, state that these holes often called vacuoles in insect histopathology do not necessarily represent vacuoles in the usual cytological sense. They may represent the precipitation of tissue constituents around some particles or droplets which are subsequently dissolved during the preparation of the sections. Thus in stained sections the vacuoles appear simply as holes with no indication as to their previous contents. In addition to vacuolization certain particles appear between the nerve cell bodies of DDT treated larvae. Large amounts of these particles occur also between the dorsal nerve cells.

Effect of Toxaphene (Figs. 44 and 49)

Toxaphene causes a marked degeneration of the nuclei of the nervous tissue cells of treated larvae. The nerve fibers as well as the nerve cell bodies of the nerve genglia become granular in appearance due to the formation of various kinds of particles. Such granular bodies exist both outside and inside the fibers. Those granules which develop within the fibrous mass are found aggregated into masses or groups.

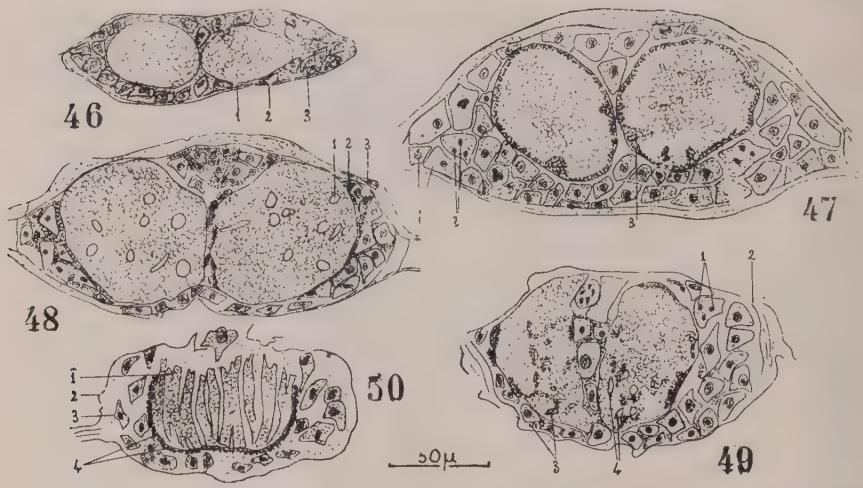

Fig. 46 : Transversal section through a ventral nerve ganglion of a healthy worm : (1) neuropile mass; (2) nerve cell; (3) neurilemma. — Fig. 47 : Transversal section in a ventral nerve ganglion of Parathion treated larva : (1) nerve cell; (2) degenerated nucleus; (3) small granules among nerve fibers. — Fig. 48 : Transversal section through a ventral nerve ganglion of DDT poisoned worm : (1) vacuoles within fibrous mass; (2) pigmented particles; (3) nerve cell. — Fig. 49 : Transversal section through a ventral nerve ganglion of Toxaphene poisoned insect : (1) broken nucleus of a nerve cell; (2) destroyed neurilemma; (3) granules aggregated in groups; (4) vacuoles within fibrous mass. — Fig. 50 : Transversal section in a ventral nerve ganglion of cotton dust treated worm : (1) destroyed neuropile mass; (2) torn neurilemma; (3) nerve cell showing destruction of chromatin (chromatolysis); (4) granules surrounding neuropile mass.

Vacuolization of the nerve fibrous mass also takes place as a result of the present treatment.

The neurilemma of such fibers is as well partly destroyed in various parts. In case of the nerve cells similar granules are also observed between the cell bodies lying laterally, dorsally and ventrally.

Effect of Cotton dust (Figs. 45 and 50)

Here the neurilemma covering the dorsal part of the nerve ganglion becomes torn. The neuropile is destroyed being divided into several parts by fissures leaving cavities between the torn parts (sections).

Surrounding the neuropile mass on both its ventral and dorsal sides appear certain particles or granules which do not exist on its dorsal side. Most noticeable is the effect of cotton dust on the nerve cell nuclei where chromatolysis occurs resulting in complete dissolution of the chromatin therein.

Blood

A. Normal blood (Fig. 51)

The main four groups of blood cells previously recorded in caterpillars by Cameron (1934), Steinhaus (1949) and others are here noticed and are the following: (1) he lymphocytes, which are round, oval, irregular or spindle shaped characterised by having deeply staining round or oval nuc'ei and scanty well staining cytoplasm; 2) the leucocytes, generally much larger than the lymphocytes, sp'ndle shaped with extended processes and possess small oval or round deeply staining nuclei occupying a central or peripheral position. In this type of cells the amount of cytoplasm is

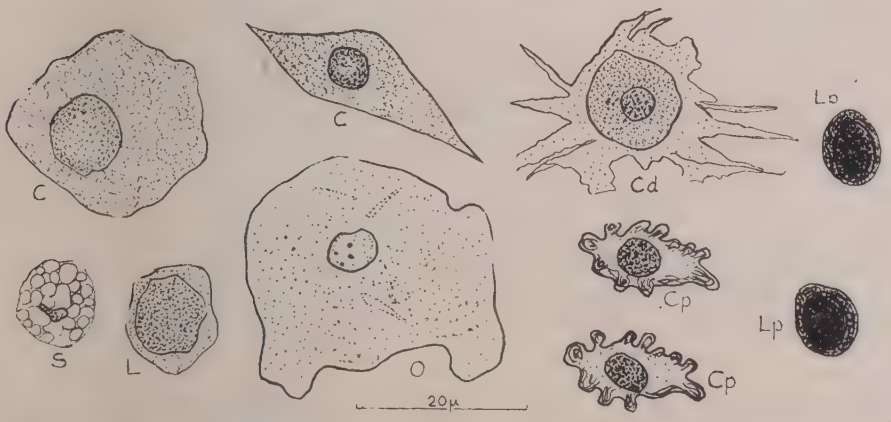

Fig. 51 : Blood cells of the healthy cotton leaf worm: (C) leucocyte, (L) lymphocyte, (S) spherule, (O) oenocyte; blood cells of a poisoned cotton leafworm: (Cd) leucocyte affected by DDT and Toxaphene, (Cp) leucocyte affected by Parathion and Toxaphene, (Lp) lymphocyte affected by Parathion and Toxaphene, (Sp) spherule affected by Parathion and Toxaphene.

comparatively great and is faintly stained, homogeneous and fequently vacuolated; (3) spherules, having the same size as the lymphocytes filled up with coarse spherules which hide the nuclei. The spherules are regularly discharged from such cells leaving vacuoles in place; (4) oenocytes, which are large cells with homogeneous and very small well stained nuclei and finely striated cytoplasm. The ratio between these various types of cells is subject to considerable variation depending on the difference in types of insects, variation in developmental stages, physiological conditions, etc.

Counts of the various types of blood cells under different conditions have been studied by many authors (METALNIKOV, 1927; CAMERON, 1934).

B. Poisoned blood (Fig. 51)

During the present study the blood of the cotton leafworm larva (at the fifth stage) showed variable changes as a result of poisoning by the different insecticides used here.

Effect of Parathion

Of the four insecticides investigated here, Parathion expressed the most pronounced haematological changes. It caused desintegration and destruction of the various blood cells. The spherule cells and lymphocytes in this case develop darkly staining nuclei and cytoplasm. The vacuoles in the spherule cells completely disappear as a result of this treatment. The leucocytes also develop broad pseudopodia-like bulgings. Such symptoms are similar to those recorded by YEAGER and MUNSON (1942) upon using mercuric chloride, fluorides, and arsenicals on the migratory locust.

Effect of DDT

DDT poisoning results at present in slight change limited to the leucocytes which show a degeneration in their cytoplasm developing fine processes that bulge from the surface. On the other hand the spherules and the lymphocytes are not affected by this insecticide.

Effect of Toxaphene

Similar to both parathion and DDT, toxaphene resulted in a destruction of some of the lymphocytes and leucocytes as well as the spherules. No particular symptoms characterise the action of this poison on the blood cells of he worm.

Effect of Cotton-dust

Cotton dust brought no effect on blood cells at present, a condition similar to that noticed in case of using nicotine insecticides, rotenone, pyrethrum and phenothiazine on the migratory locust by YEAGER and MUNSON (1942).

VI. DISCUSSION AND CONCLUSIONS

Among newer chemicals recently applied for insect control chlorinated hydrocarbons and the synthetic organic phosphorous compounds are considered the most efficient. The results of laboratory experiments carried on here on the effeciency of these compounds as ovidcides and larvicides confirm the field findings of previous workers (WEISMAN, 1952; HASSAN et al., 1956) and will appear in a separate publication.

The changes in the histopathological picture in case of the different insecticides used at present are also due to differences in their types as well as to the variation in sensetivity and response of the various cells and tissues to the insecticides concerned. This might also be dependent on the amount of poison that reaches or that is absorbed by these tissues.

The variation in mode and extent of action of the different insecticides on the worms has been a subject of considerable discussion among various authors. Most of the contact insecticides, as those used here, are considered to act through inhibiting the various enzymatic activities, resulting in the commonly encountered histopathological symptoms. Detailed microchemical analysis and elaborate physiological studies are necessary to confirm such suggestion.

During the present study Parathion, DDT, Toxaphene, Cotton-dust, all succeeded in causing histopathological destruction to the tissues of the mid-gut, fat body, muscular system, Malpighian tubules and nervous system. Other tissues show no detectable symptoms in the studied worms.

The tissues which show symptoms here are not affected to the same extent or in the same way, depending on their degree of susceptibility and nature of each of these tissues. The tissues that show no destruction in the present study, may either be resistant to the insecticides used here or require comparatively longer time for the symptoms to show up. The larvae on which symptoms are studied here have been fixed before death for the fear of confusion by postmortem changes. The tissues, considered unaffected, may also be susceptible to these insecticides but to a lesser extent. Such tissues, therefore, might be affected if more time is allowed for the poison to act thereupon. However, the fear of the interference of the postmortem changes makes it unadvisable to allow the treated insects stand extra time before fixation.

The histopathological symptoms brought about to the larval tissues by the chemicals in the present study are somewhat similar to those caused by various insect diseases as those reported upon by STEINHAUS (1949).

The structural alterations caused to the body tissues in case of diseases are certainly due to the action of chemical poisoning due to by-products secreted by the pathogenic microorganisms within the concerned tissues. Since the destruction of any specific tissue would finally affect the insect in much the same way regardless of the poison employed, it is probable that insecticides affect insects just in the same way as certain diseases do. However, as can be grasped from the results of the present investigation, each poison or group of poisons usually elicits its own peculiar reaction and produces its own particular pattern of pathological changes. Such destruction may be quitecomplex and may involve several tissues orsystems of the insect body as noticed here. The mode of action of insecticides upon insect tissues has been a subject of considerable contradiction among various authors.

The considerable histopathological damage caused by each of the insecticides used at present suggests that once any of these chemicals gain enterance to the insect tissues, by contacting its body in excessive quantities, will bring the death of the

individual concerned. Thus in field application of such chemicals considerable attention should be paid to the method of application. This should be done in such a way to ensure the poison coming in contact with the insects in sufficient amounts.

Field use of a certain chemical, however, should be always preceeded by a laboratory test for its general and histopathological effect on the insect concerned. Preference between various insecticides should be based on the effeciency as shown in the laboratory experiments. The more the effeciency of an insecticide in causing histopathological destruction in comparatively lesser time is, the more valuable this material is in insect control. Other than these measures certain factors such as the stability of in ecticide under field conditions, the environmental conditions, and the biotic potential of the insect have to be taken into consideration before reaching definite conclusions concerning the success of insecticides in the control of insects in the field.

In case of blood, the destruction caused by the various insecticides at present is not specific, a fact that makes the histopathological picture of the blood unreliable and nonconclusive. The difficulty in analyzing the poisoning symptoms in case of blood may be due to the considerable difficulties in differentiating the normal and abnormal blood cells; a fact that makes the influence of poisons on insect blood most undiscoverable.

The reason why the effect of cotton-dust is studied, although it is an insecticide of a complex nature, rather than studying its components separately is that this compound is commonly used in Egypt as such for the control of the cotton leafworm with comparatively successful results. In addition the histopathological malformation picture caused by this dust may not be necessarily the same as that of the materials entering in its formation when such effects are added together, since synergism is supposed to change the results.

VII. SUMMARY

The present investigation deals with the study of the destruction caused by four insecticides namely Parathion, DDT, Toxaphene and Cotton-dust, to the body tissues of the cotton leafworm larva at the third instar.

These insecticides were found to share in causing histopathological destruction to tissues of the mid-gut, Fat body, muscles, Malpighian tubules, central nervous system and blood. The detailed pattern of destruction caused to these tissues varies to a considerable extent in ca e of each of these four insecticides.

Parathion caused : (1) Detachment of the muscular coat of the mid-gut from the epithelium and an exfoliation of the latter from the destroyed basement membrane. with an elongation and vacuolization of the epithelial cells. The boundaries of the epithelial cells are also destroyed and the nuclear ch omatin gathers forming irregular lumps with rough appearance. Some of these cells are torn and

the peritrophic membrane disappears completely. (2) Vacuolization of the fat-tissue cells and shrinkage of their nuclei to such an extent that they are easily overlooked and might be considered absent. (3) Loss of normal turgidity and striations of muscles and the appearance of fissures by being torn into separate parts. (4) Degeneration of the Malpighian tubules cell nuclei and a decrease in the lumen of the tubules as a result of the increase in thickness of the cells. This insecticide treatment results also in the appearance of deeply stained particles in the lumen of the tubules. (5) Appearance of granules around the neuropile mass and clumping of the chromatin mass of the nerve cells with a degeneration of the nuclei.

DDT resulted in : (1) Folding of the circular muscle layer of the mid-gut and its slight detachment from the epithelium. It also causes exfoliation of the epithelium from the basement membrane in large sheets with the cells in such sheets generally keeping their normal histological characters. The nuclei of the epithelial cells become elongated having ampullae-like appearance with granular particles filling it up. In addition vacuolization and detachment of small parts of the inner border of the epithelial cells occur as a result of DDT treatment. (2) Separation of fat-body cells from each other and shrinkage of their cytoplasm and clumping of chromatin into rod-shaped masses. (3) Appearance of fissures in the muscles and their breaking down into small portions due to destruction of the sarcolemma. (4) Degeneration of the nuclei and vacuolization of the Malpighian tubules cells and in increase of the lumen of the tubules as a result of shrinkage of the cytoplasm of its cells. The epithelium of the Malpighian tubules walls is partly desintegrated with some of the degenerated parts falling within the tubules lumen. (5) Vacuolization of the nerve fibrous mass and the appearance of certain granules among the nerve cells particularly among those at the dorsal part of the ganglion fo the ventral nerve cord.

Toxaphene caused : (1) Desintegration and destruction of the mid-gut epithelium and its exfoliation from the basement membrane, as well as the appearance of vacuoles inbetween the cells. The nuclear chromatin is clumped and is broken into several parts. (2) Vacuolization of fat-cells and destruction of the membranous sheath surrounding them. This is also accompanied with shrinkage of the cytoplasm and nuclear degeneration of this tissue. (3) Destruction of the muscular fibers and the surrounding sarcolemma as well as the breaking down of the muscular bundles into parallel divisions without the fibers themselves loosing their characteristic striations. (4) The clumping of the nuclear chromatin of the Malpighian tubules cell nuclei into-rod-like masses leaving a clear outside peripheral area just lining the nuclear membrane. (5) Degeneration of the nervous tissue cells and the granulation of the nerve fibers and cells. Aggregation of such granules is noticed among the fibers. The neurilemma is here also partly destroyed.

Cotton-dust resulted in: (1) Detachment of the mid-gut epithelial layer from the underlying musculosa. Within the musculosa the longitudinal muscle fibers are much degenerated loosing their normal appearance and developing various

fissures. The epithelium itself is much desintegrated and completely destroyed in some regions with disappearance of the boundary lines inbetween the constituent cells. These cells are broken into various parts which fall within the lumen of the mid-gut. The nuclear chromatin of these epithlial cells is clumped into rough irregular lumps of granular structure. This is accompanied with the destruction of the peritrophic membrane as well. (2) Destruction of the membranous sheath around the fat-tissue cells with clumping of the nuclear chromatin of these cells which are also vacuolized. (3) Vacuolization and loss of turgidity of the muscles and the breaking down of the fibers. In addit on clumping of the nuclear chromatin of the nuclei and tearing of the sarcolemma are noticed. (4) Collapse of the Malpighian tubules due to their shrinkage thus resulting in disappearance of the lumen. Certain particles are seen blocking the lumen. Such particles are arranged in parallel strands. The nuclear chromatin of the Malpighian tubules cells is clumped into a compact densely coloured mass. (5) The destruction of the neurilemma of the ventral nerve ganglia of the central nervous system. The breaking down of the neuropile into several parts with the appearance of several cavities inbetween also resulted. Various granules appear around the dorsal and lateral sides of the ganglion. This is also accomapied with chromatolysis of the nerve cell nuclei.

In addition to the differences in the nature of the histopathological damage caused to the insect tissues by these insecticides the time taken for their appearance vary accordingly.

The four poisons used here (Parathion, DDT, Toxaphene and Cotton-dust) vary also considerably as far as their effect on the blood cells of the cotton leafworm is concerned. Parathion caused desintegration and degeneration of the various blood cells. DDT expressed its effect on the leucocytes only. Toxaphene caused certain changes (symptoms) to the blood cells of the worm similar to these met with in case of Parathion and DDT. Cotton-dust poisoning caused no observable changes in the blood cells.

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HOST-PLANTS OF THE CEREAL LEAF-MINER, *SYRINGOPAIS TEMPERATELLA* LED., IN CYPRUS

[*Lepidoptera*: *Elachistidae-Scythridinae*]

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In his comprehensive monograph on the cereal leaf-miner, SARACOMENOS (1908) mentions that although cereals are the preferred host of the larvae of this insect, they also feed on the leaves of *Sinapis nigra*, *Plantago major*, *Plantago minor*, *Tropaeolum* sp. and "dog grass" and on the flowers of *Convolvulus arvensis*. Subsequent investigators in other countries have also indicated that the feeding of the cereal leaf-miner is not restricted to cereals (HUSSEINI, 1954), but no names of other host plants were given except by RIVNAY (1956) who reported having seen in 1942 an "entire clover field which had been so heavily attacked that advice on control of the pest was sought". He also stated that similar infestations had been observed since.

The authors have observed on several occasions larvae of the cereal leaf-miner in leaves of weeds growing in and around cereal fields, and during the last three years have kept records of such plants. A total of 31 new host plants are recorded below together with six plants mentioned by previous authors.

PREFERRED HOSTS

GRAMINEAE : *Hordeum vulgare* L., *Triticum vulgare* Vill., *Triticum durum* Desf., *Avena sativa* L.

OTHER HOSTS

CARYOPHYLLACEAE : *Silene venosa* Aschers.

COMPOSITAE : *Asteriscus aquaticus* Less., *Broteroa corymbosa* Willd., *Carduus pycnocephalus* L., *Centaurea hyalolepis* Boiss., *Cirsium lanceolatum* Scop., *Cirsium syriacum* Gaertn., *Cynara sibthorpiana* Boiss., *Onopordon sibthorpianum* Boiss., *Scolymus maculatus* L., *Silybum marianum* Gaertn.

CONVOLVULACEAE : *Convolvulus althaeoides* L., *Convolvulu arvensis* L., on flowers (SARACOMENOS).

CRUCIFERAE : *Hischfeldia incana* L., *Sinapis arvensis* L., *Sinapis nigra* L. (SARACOMENOS).

DIPSACACEAE : *Scabiosa prolifera* L.

EUPHORBIACEAE : *Mercurialis annua* L.

GERANIACEAE : *Erodium malacoides* Willd., *Erodium moschatum* L.

GRAMINEAE : *Avena ludoviciana* Dur., *Avena* sp., *Bromus* sp., *Lolium* sp., *Phalaris paradoxa* L. var. *praemorsa* (Lam.) Coss.

LABIATAE : *Salvia horminum* L., *Salvia verbenacea* L.

LEGUMINOGAE : *Circinnus circinnatus* O. Ktze, *Melilotus* p. (?) *officinalis* L., *Trifolium* (? sp.) (RIVNAY).

MALVACEAE : *Hibiscus trionum* L.

PLANTAGINACEAE : *Plantago lanceolata* L., *Plantago* sp. (? *minor*) (SARACOMENOS), *Plantago major* L. (SARACOMENOS), *Plantago psyllium* L.

ROSACEAE : *Poterium* (*Sanguisorba*) *spinosum* L.

TROPAEOLACEAE : *Tropaeolum* sp. (SARACOMENOS).

No systematic rearing of the insect on the above hosts was carried out. In most field collections however, the larvae were in an advanced stage of development, so that there can be but little doubt that the insect is capable of completing its development on these hosts. In a few instances where infested plants were kept in the laboratory adults invariably emerged.

The insect appears to be more common on weeds grown just outside cereal fields than on weeds within cereal fields. It is assumed that most of the larvae present in the field prefer to feed on cereal plants, while those outside being too small to return to cereals have no alternative but to feed on other host species. These larvae may have been taken outside the field with soil during the summer and autumn cultivations. In fact most of them were present within a distance of up to 3 yards from cereals, which is approximately the cultivation headland.

A search was carried out for larvae of the insect on weeds growing in infested fields during the fallow year. No larvae were found, and it is most likely that whatever larvae enter weeds on fallow land they are soon consumed by livestock. Larvae of the insect were found, however, on weeds growing among vetches in infested fields where a two year rotation (cereals-vetches) is followed.

In order to gain some information on the extent of the distribution of the insect on non-grazed land adjoining infested cereal fields a survey was carried out in a nearby state forest area. Larvae of the insect were found on a number of species up to a distance of about 100 yards from infested fields. Beyond that, the larvae were extremely rare. There appeared to be more larvae along paths leading away from cereal fields, than where man has no easy access.

The presence of the insect on weeds at such distance from infested fields might be attributed to accidental transportion of larvae by man either in soil during summer and autumn, or with infested plants in winter. It may also be due to oviposition by moths which drift away from cereal fields and, being weak fliers, cannot return in time to their preferred hosts for oviposition.

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CLASSIFICATION OF THE SCALE INSECTS, FAMILY *DIASPIDIDAE*, AS KNOWN TO OCCUR IN EGYPT

[*Homoptera*: *Coccoidea*]

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INTRODUCTION

In 1937, FERRIS introduced the first volume of his Atlas by stating that the family *Coccidae* must be stepped up at least to a superfamily to provide a better graded series of categories for the thousands of species still to be discovered. The idea of a superfamily for the coccids began several years before the appearance of FERRIS' Atlas. It started when certain coccid groups, which had been included in subfamilies, were recognized by different coccidologists as forming families. The name *Coccidoidea* had been once proposed to designate this superfamily, but soon rejected for impropriety and replaced by the name *Coccoidea*. At the beginning of the Atlas, FERRIS recommended to recognize, within the *Coccoidea*, eleven families to include the North American species. These families are : *Aclerdidae*, *Asterolecaniidae*, *Coccidae*, *Conchaspididae*, *Dactylopiidae*, *Diaspididae*, *Kermidae*, *Lacciferidae* (=*Tachardiidae*), *Margarodidae* *Ortheziidae* and *Pseudococcidae*. Several volumes of FERRIS' Atlas have come out, dealing with the North American species of the families *Diaspididae*, *Pseudococcidae*, *Aclerdidae*, *Asterolecaniidae*, *Conchaspididae*, *Dactylopiidae*, and *Lacciferidae*; while still other volumes of the Atlas are expected to appear dealing with certain other families. Moreover, CHAMBERLIN published about *Lacciferidae* in 1925, STEINWEDEN classified the genera of the family *Coccidae* in 1929, MORRISON worked out *Margarodidae* in 1928 and *Ortheziidae* in 1952, MCCONNELL classified the family *Aclerdidae* in 1953, and MAMET published a monograph of *Conchaspididae* in 1954.

On the other hand, BALACHOWSKY in 1956 recognized in the superfamily *Coccoidea* four families only: *Conchaspidae* (properly *Conchaspididae*), *Diaspididae*,

Lecanidae, and *Margarodidae*. In an earlier volume, 1948, he had distinctively recognized the latter three families only, considering that the family *Diaspididae* includes two subfamilies, *Diaspidinae* and *Phoenicococcinae*; while *Lecanidae* includes ten subfamilies, *Apiomorphinae*, *Astrolecaniinae*, *Conchaspinae* (properly *Conchaspidinae*), *Cylindrococcinae*, *Dactylopinae*, *Kerminae*, *Lacciferinae*, *Lecaniinae*, *Phenacoleachinae*, and *Stictococcinae*; and *Margarodidae* including two subfamilies, *Margarodinae* and *Ortheziinae*. Later on, BALACHOWSKY recognized the family *Coonchaspididae* after the appearance of MAMET's monograph about this family.

The previous paragraphs are just to represent the recent status of *Coccoidea* as recognized to include eleven families by FERRIS, or to include three or four families only by BALACHOWSKY. However, although the aim of this paper is not to compare between these two classificatory systems, it is interesting to note that most of the families recommended by FERRIS are now accepted by many authors and quite established; while the other families are expected to achieve a similar result.

The main purpose of the present work is to construct usable keys leading to the identification of the scale insects, family *Diaspididae*, as known to occur in Egypt. These keys had to be preceded by other preliminary keys treating the family *Diaspididae* downwards to its genera. The alphabetic arrangement represented in the different sections of this paper has, of course, no phylogenetic significance.

Since keys are generally used as an aid toward identification, it is always advisable to refer to the text of corresponding species before final determination. Fortunately, all the species here included except some of HALL's species, have been recently well redescribed by many authors of the field, and a trial to redescribe any of them, at least for the time being, is considered useless and therefore avoided. Undoubtedly, certain species of those described by HALL have been subjects to recent nomenclatorial changes by several authors in different parts of the world. Some of these very recent changes are not here considered regarding that the redescription of HALL species from Egypt constructs a definite Egyptian job that has to be handled in details as a separate piece of work. However, further collecting of material and more literature are needed to accomplish such job.

This work has been done in the Department of Entomology, Ministry of Agriculture (Egypt), with the approval of the Department of Plant Protection, College of Agriculture, Ein Shams University (Egypt). Aknowledgement is due to these Departments for providing the facilities of the study. Credit has to be given to both Prof. FERRIS of Stanford University (California), and to Prof. BALACHOWSKY of the Pasteur Institute (Paris), for making use of their ideas in taxonomy. Gratitude is here expressed to Dr. MORRISON of the U.S. Department of Agriculture as well as to Prof. MCCONNELL of the University of Maryland, for supporting the work with many useful suggestions. Thanks are also due to Prof. Dr. H. PRIESNER of the College of Science, Ein Shams University, for reading the manuscript.

Particular names here included may represent certain errors in their construction. However, nothing could be done towards correcting such names simply

because the intention here is to follow the International Rules pertaining to "original orthography". Each of *Diaspis boisduvalii* Sign., *Lepidosaphes gloverii* (Packard), and *L. beckii* (Newman) has an extra "i" at the end; *Parlatoria pergandii* (Comst.), being dedicated to PERGANDE, should have been *P. pergandei*; and *Parlatoria zizyphus* (Lucas) should have been *P. zizyphi*. In short, these names should have been different than what they actually are, but according to the International Rules of Zoological Nomenclature, neither misspelling nor inappropriateness of a name are valid reasons for amending the original orthography. This procedure prevents any confusion in later years when workers are concerned with two names spelled nearly alike, but actually. different.

It should be noticed that certain species in the following keys are not represented in the collection of the Ministry of Agriculture. These species are: *Leucaspis quadrispinosa* Green, *Rhizaspidiotus artemisiae* (Hall), *Abgrallaspis seurati* Marchal, *Lepidosaphes gloverii* Packard, *Marganella longispina* (Morgan), *Pinnaspis buxi* (Bouché), and *Pseudaonidia trilobitiformis* Green. The first two species are included in the keys on the basis of having been described from Egypt. The rest of these species are included because of having been intercepted at the American ports on plants imported from Egypt and they are in the United States National Collection among the Egyptian material.

SYSTEMATICS

Family DIASPIDIDAE

RECOGNITION CHARACTERS: Coccoidea without abdominal spiracles; cuticle of female in all instars with tubular ducts having a central bulla and never a lateral filament; anus of larva and adult neither opens in a rigid anal ring nor with anal plates; mentum generally one-jointed; legs of female never well developed at maturity, usually entirely lacking or sometimes vestigial; male diaspidoid, head fused with prothorax without any trace of a neck, with ocelli only, never with lateral compound eyes.

Key of the subfamilies

a. Adult female without a scale composed of exuviae and secretionary material; without any structure to indicate segmental lines on dorsum of the pygidial area; pygidium, if present, includes no segments anterior to segment VI; anal ring sclerotized. Male always wingless; with short antennae, not exceeding one half of the body length ..... **Phoenicococcinae**

aa. Adult female with a scale compos ed of exuviae and secretionary material; with some segmentally arranged structure; segments V to VIII and at times IV to VIII are fused into a pygidium (except in tribe *Xanthophthalmini*); anal ring not sclerotized. Male winged or secondarily wingless; provided with long antennae, exceeding one half of the body length ..... **Diaspidinae**

Subfamily DIASPIDINAE

Key to the tribes

1. Abdominal segments V to VIII of the adult female not fused into a pygidium ..... **Xanthophthalmini**
   Abdominal segments V to VIII of the adult female fused into a pygidium 2

2. (1) Pygidium of adult female never with plates, rarely with gland spines; lobes absent or reduced to a fused median pair; macroducts short, abundant both dorsally and ventrally, disposed on the two surfaces of the pygidium without definite order or proper arrangment; microducts generally present on the ventral surface of the pygidium; second exuvia usually of the bivalve type ..... **Odonaspidini**
   Pygidium of adult female normally with plates or gland spines; lobes generally well developed and not fused; macroducts more numerous on the dorsal surface of the pygidium where they are disposed in proper and regular order, than on the ventral surface where they are less numerous or frequently wanting; exuvia occasionally of the bivalve type..... 3

3. (2) Pygidium of adult female without plates, with gland spines only; second pair of lobes generally bilobulate. First instar larva with 5 or 6 jointed antennae with the last one usually shorter than all the rest grouped together and not annulate; with two cephalo-dorsal paired macroducts .. **Diaspidini**
   Pygidium of adult female usually with plates, with or without gland spines; second pair of lobes never bilobulate. First instar larva with 5-jointed antennae with the last one usually longer than the other four joints grouped together and annulate in all its length; withou cephalo-dorsal paired macroducts..... 4

4. (3) Macroducts of the two-barred type, disposed on isolated elements or in regular order on the different pygidial areas; plates obviously of equal size, denticulated, existing or wanting beyond the pygidial segments of the adult female. ..... **Parlatorini**

Macroducts of the one-barred type, disposed mostly in the glandiferous marginal or submarginal farrows or crypts of the different pygidial areas; plates generally unequal, of variable forms, i.e. spiniform, ra nose, divided, denticuled at their extremity or external edge, rarely absent or diminished, always wanting beyond the pygidial segments of the adult; female.... ..... **Aspidiotini**

Tribe ASPIDIOTINI

Key to the genera

Adult female

1. Prosoma with a deep lateral invagination at the level of mesothorax, i.e. with a prosomatic area set off by a strong construction from the remainder of the body 2
   Not with a prosomatic area 3
2. (1) Pygidium with two pairs of distinct lobes (L_1 L_2), L_3 absent or degenerated; paraphyses of segments VI and VII well marked; plates absent on segment VI; perivulvar pores always absent; anal opening situated in the apical region of the pygidium. ..... **Pseudotargionia Lindinger**
   Pygidium with four pairs of well developed lobes (L_1, L_2, L_3, L_4); paraphyses absent or reduced to weak intersegmentary marginal scleroses; plates always present on segment VI; perivulvar pores always present; anal opening situated slightly behind the center of the pygidium .... **Pseudaonidia Cockerell**
3. (1) Adult female pupillarial, i.e. remaining within the second instar exuvia which is generally of vitreous structure; macroducts of the pygidium reduced to isolated marginal elements ..... **Aonidia Targioni**
   Adult female not pupillarial; macroducts of the pygidium grouped in marginal, submarginal, and sutural elements, on the different pygidial areas..... 4
4. (3) Pygidium beset with dorsal and ventral ducts of approximately the same number, diameter, and structure, numerous, filiform, with circular minute pores, generally opening in well defind furrows running over the different pygidial areas; plates absent or very reduced and spiniform; ventral scale uniting with the dorsal scale to form an almost closed capsule 5
   Pygidium beset with dorsal macroducts, always more numerous than the ventral microducts and with obvious larger diameter, cylindrical or filiform, with clearly oval or exceptionally circular pores, disposed in oblique bundles, sometimes opening in the pygidial areas and sometimes in the intersegmental crypts of the pygidial margin; microducts less numerous or wanting, filiform and with circular pores; plated generally well developed and finely fringed; ventral scale mostly absent 6

5. (4) Dorsal macroducts of pygidium with very long filiform tubules; ventral microducts of pygidium arranged in oblique rows over the whole pygedial area; intersegmental furrows delimiting the pygidial segments, separating segments V to VIII, generally well marked at least in their apical third; median and lateral lobes quite apparent ..... **Targionia Signoret**
Dorsal macroducts of pygidium with relatively short filiform tubules; ventral microducts of pygidium without definite order on the whole or a part of the pygidium; intersegmental furrows of the pygidium absent or very weakly apparent; L_1 only developed, L_2 and L_3 when present are more or less confused with the marginal cuticular thickenings of the pygidium ..... **Rhizaspidiotus MacGillivray**

6. (4) Pygidial margin without paraphyses or intersegmentary scloroses between segments VI and VIII 7
Pygidial margin with paraphyses or intersegmentary scleroses between segments VI and VII or VII and VIII. These last may be reduced to weak thickenings (genus *Abgrallaspis* Balach.) 10

7. (6) Pygidium with only L_1 well developed, L_2 and L_3 either absent or reduced to minute tuberculiform marginal protuberances; dorsal macroducts of the pygidium very f w in number, of reduced diameter and filiform tubules ..... **Morganella Cockerell**
Pugidium with two, three, or four pairs of well developed lobes; dorsal macroducts of pygidium numerous, with cylindrical tubule and oval opening of the classical aspidiotiform type 8

8. (7) Cephalothoracic cuticle without thickening; L_1, L_3 perceptibly parallel to one another 9
Cephalothoracic cuticle thickened or not; L_2 and L_3 either convergent or divergent..... **Aspidaspis Ferris**

9. (8) L_1, L_2 and generally L_3 perceptibly equal in size; L_4 indicated by a definite sclerotized point; plates small, variously fringed ..... **Dynaspidiotus Thiem and Gerneck**
L_1 distinctly stouter than L_2 and L_3; L_4 completely absent; plates strongly developed, with characteristic fine fringes ..... **Aspidiotus Bouché**

10. (6) Lateral and external plates (segment VI) stout, exceeding L_1 and L_2 in length 11
Lateral and external plates (segment VI) small, degenerated, not exceeding L_1 and L_2 in length, sometimes completely lacking 14

11. (10) Cephalothoracic cuticle thickened, corneous; thoracic lobes laterally turned down and encircling the pygidium; or if this character is absent (*Aonidiella orientatis* Newst.), three differentiated, cultriform, external plates are present on segment VI ..... **Aonidiella Berlese and Leonardi**

Cephalothoracic cuticle not thickened, membranous; thoracic lobes never turned down laterally on the pygidium; external plates (segment VI) differentiated or not 12

12. (11) Pygidial margin only with intersegmentary scleroses or thickenings between VI and VIII and not with fusiform paraphyses; external plates (segment VI) absent, or not much differentiated, perceptibly identical to the lateral plates. 13

Pygidial margin with five to seven pairs of long narrow fusiform paraphyses; external plates (segment VI) differentiated, cultriform or divided... ..... **Chrysomphalus Ashmead**

13. (12) Anal opening situated very low, in the apical region of the pygidium; L_2 and L_3 degenerated, spiniform intersegmentary scleroses between VI and VII, and VIII stout, recurved, forming crypts; filiform plates stout and divided ..... **Hemiberlesia Cockerell**

Anal opening situated at the level o th apical third or forth of the pygidium; L_2 and L_3 when present) more reduced han L_1 but neither degenerated nor spiniform; intersegmentary scleroses between VI and VII, and VII and VIII scarcely marked; dorsal macroducts of the classical cylindrical aspidiotiform type; plates normally denticulate.. **Abgrallaspis Balachowsky**

14. (10) Paraphyses short, fusiform, thickened or reduced to simple scleroses, bordering the intersegmentary spaces of segments VI and VII, and VII and VIII only; margin of segment V neither thickened nor sclerotic, always without paraphyses ..... **Quadraspidiotus MacGillivray**

Paraphyses many and stout on the margins of segments VI to VIII; apical margin of segment V strongly thickened or covered with small paraphyses increasing in size from before backwards, or formed of several equidistant dentiform identations 15

15. (14) Cephalic region with a large projecting nipple; thoracic tubercle situated at the level of the eye; body circular in shape .. **Mycetaspis Cockerell**

Cephalic region entirely without a nipple; Thoracic tubercle metapleural or absent; body pear-shaped. 16

16. (15) Thoracic tubercle thick, fleshy, metapleural; L_1, L_2, L_3 perceptibly identical to one another in size and shape; paraphyses of segments VI to VIII identical, slender, and fusiform; median and lateral plates large, denticulate, generally reaching the length of the respective lobes .. **Lindingaspis MacGillivray**

Thoracic tubercle present or absent; L_1, L_2, L_3 progressively increasing in size; paraphyses thick, fusiform, unequal in size; median and lateral plates degenerated, short, spiniform, generally not reaching the length of the respective lobes. ..... **Melanaspis Cockerell**

NOTE: Balachowsky, in 1948, dealing with the tribe *Aspidiotini*, proposed five subtribes to include the various genera of this tribe. However, the above key classifies the tribe directly to its seventeen genera known to occur in Egypt. The subtribes are represented in this key as follows : Couplet No. 2 represents the two genera of the subtribe *Pseudaonidina*; the first part of couplet No. 3 represents the key characters for the subtribe *Aonidina*, from which only the genus *Aonidia* is known to be in Egypt; Couplet No. 5 includes the two genera of the subtribe *Targionina*; and the rest of items classifies the genera from the subtribe *Aspidiotina*. The fifth subtribe, *Selanespidina*, is not known to be represented in Egypt, hence does not appear in this key. It is similar to *Pseudaonidina* in being with a prosomatic area, but differs by lacking peristigmatic pores, reticulum generally absent in the central area of the two surfaces of the pygidium, and lobe 3 always transformed to a spiniform process.

Genus ABGRALLASPIS Balachowsky

Key to the adult females

a. L_3 completely absent; dorsal macroducts absent on segment VII (between L_1 and L_2); perivulvar pores absent ..... **seurati (Marchal)**

aa. L_3 sunk and spiniform, short; dorsal macroducts present on segment VII (between L_1 and L_2); perivulvar pores present, arranged in four groups ..... **cyanophylli (Signoret)**

Genus AONIDIA Targioni

One species only..... **lauri (Bouché)**

Genus AONIDIELLA Berlese and Leonardi

One species only..... **aurantii Maskell**

Genus ASPIDASPIS Ferris

One species only..... **longiloba (Hall)**

Genus ASPIDIOTUS Bouché

Key to the adult females

a L_2 of same shape shape and obviously same structure as L_3; dorsal macroducts long, more than five times as long as wide, arranged in oblique rows on segments VI to VIII ..... **destructor Signoret**

aa. L_2 distinctly more developed than L_3, which is conical or spiniform; dorsal macroducts short, about three times as long as wide, arranges in oblique rows on the different pygidial area ..... **hederae Vallot**

NOTE: HALL, 1923, separated *A. hederae* var. *urenae* as a new variety, mainly on the basis of fewer dorsal macroducts than in typical *hederae* Vallot.

Genus CHRYSOMPHALUS Ashmead

Key to the adult females

a. External plates on pygidium are strong cultriform; abdominal segment II with two marginal dorsal small ducts only; the scale brick red in colour, slightly translucent, with the larval exuvia dark browm or having browm rings on light base. ..... **dictyospermi (Morgan)**

aa. External plates on pygidium are not cultriform, but branched and denticuled with club-shaped pracesses; abdominal segment II with fifteen to twenty small submarginal dorsal macroducts; the scale invariably of black colour with the larval exuvia red ..... **ficus Ashmead**

Genus DYNASPIDIOTUS Thiem and Gerneck

One species only ..... **britannicus (Newstead)**

Genus HEMIBERLESIA Cockerell

Key to the adult females

a Circumgenital pores absent; most of the macroducts of pygidium disposed in a single oblique furrow on segment VI, and a number of 2 to 4 ducts on the area of segment V ..... **rapax (Comstock)**

aa. Circumgenital pores disposed in four groups; most of the macroducts of pygidium disposed in two oblique rows parallel to each other on segments VI and V respectively ..... **lataniae (Signoret)**

Genus LINDINGASPIS MacGillivray

One species only..... **floridana Ferris**

Genus MELANASPIS Cockerell

One species only..... **inopinata (Leonardi)**

Genus MORGANELLA Cockerell

One species only ..... **longispina (Morgan)**

Genus MYCETASPIS Cockerell

One species only ..... **personata (Comstock)**

Genus PSEUDAONIDIA Cockerell

One species only ..... **trilobitiformis Green**

Genus PSEUDOTARGONIA Lindinger

One species only ..... **glandulosa Newstead**

Genus QUADRASP DIOTUS MacGillivray

One species only ..... **pyri (Lichtenstein)**

Genus RHIZASPIDIOTUS MacGillivray

One species only ..... **artemisiae (Hall)**

Genus TARGIONIA Signoret

Key to the adult females

a. Cephalothoracic cuticle not sclerotized; 4 entirely absent; dorsal macroducts represented in great number on all the dorsal area of the pygidium and on the lateral areas of the prepygidial segments II and III; internal heel of L_1 is fusiform, rounded ..... **nigra Signoret**

aa. Cephalothoracic cuticle entirely or partially sclerotized; 4 reduced but always present, triangular; dorsal macroducts exclusively distributed in the cuticular furrows and not on all the pygidial area, entirely absent on the prepygidial segments II and III; internal heel of L_1 is short, triangular ..... **haloxyloni Hall**

Tribe DIASPIDINI

Key to the genera

Adult female

1. Adult female not pupellarial, i.e. free of the preadult skin at maturity; pygidial structure better developed than in preadult 2
   Adult female pupellarial, i.e. enclosed at maturity within the preadult skin which splits about the pygidial margin to permit the escape of the larvae; pygidial structure of reduced development as compared with the preadult 12

2. (1) With gland spines between median lobes. 3
   Without gland spines between median lobes 7

3. (2) Body turbinate or stout 4
Body elongate, widest across the intermediate abdominal segments .. 5
4. (3) Body membranous except for the pygidium: median lobes protruding, with a pair of small inconspicuous gland spines between them..... ..... **Carulaspis MacGillivray**
Body with the cephalic portion tending to become sclerotized at maturity; median lobes mostly invaginated, forming a median notch, with a pair of large fimbriate gland spines between them .. **Furcadiaspis MacGillivray**
5. (3) Groups of perivulvar pores present ..... **Lepidosaphes Shimer**
Groups of perivulvar pores wanting 6
6. (5) Marginal pygidial ducts as large as dorsal ducts .... **Coccomytilus Leonardi**
Marginal pygidial ducts much larger than dorsal ducts .. **Nilotaspis Ferris**
7. (2) Body broadly oval 8
Body otherwise 9
8. (7) Median lobes invaginated, always separated, only partly protruding. ..... **Diaspis Costa**
Median lobes contiguous and strongly protruding. .... **Pseudaulacaspis MacGillivray**
9. (7) Body with swollen prosoma, and abdomen protruding from this with parallel sides ..... **Aulacaspis Cockerell**
Body elongate, with parallel sides or somewhat swollen across the intermediate abdominal segments 10
10. (9) Median lobes non-zygotic; pygidium with coarse reticulation .... **Ischnaspis Douglas**
Median lobes zygotic; pygidium without any reticulation 11
11. (10) Median lobes with inner margins straight and in close apposition throughout their length ..... **Pinnaspis Cockerell**
Median lobes with inner margins in close apposition over part of their length only ..... **Chionaspis Signoret**
12. (1) Median lobes well developed though small, making the sides of a conspicuous notch at the pygidial apex ..... **Fiorinia Targioni**
Without such notch at the pygidial apex..... ..... **Chrypthemichionaspis Lindinger**

Genus AULACASPIS Cockerell

Key to the adult females

a. Eyespot small, sclerotized; peristigmatic pores numerous, composite; on roses ..... **rosae (Bouché)**

aa. Eyespot low-dome shaped, membranous; peristigmatic pores few, not composite; on mango ..... **cinnamomi var. mangiferae Newstead**

Genus CARULASPIS MacGillivray

One species only ..... **visci (Schrank)**

Genus CHIONASPIS Signoret

Key to the adult females

1. L_1 straight or slightly convergent; with duct tubercles on the submarginal areas of thorax and anterior abdominal segments. .... **striata Newstead**
   L_1 divergent; apparently without duct tubercles 2

2. (1) L_1 long, strongly bent ..... **stantophri Cooley**
   L_1 short, not bent ..... **noaeae Hall**

Genus COCCOMYTILUS Leonardi

One species only ..... **farsetiae Hall**

Genus NILOTASPIS Ferris

Key to the adult females

1. Dorsal ducts of pygidium irregularly scattered, few of these are present on submarginal and submedian areas of segments VII and VIII; antennae with several setae of variable size ..... **retamae (Hall)**
   Dorsal ducts of pygidium arranged in obvious rows on the submarginal and submedian areas of segments other than VII and VIII; antennae with two large setae only 2

2. (1) Gland spines between median lobes short, barely exceeding the tips of the lobes; submedian dorsal ducts on abdomen present on rows on segments III to VI ..... **isis (Hall)**
   Gland spines between median lobes long and slender, projecting two or three times the lobe length beyond the tips of lobes; submedian dorsal ducts on abdomen present on segments V and VI only .. **halli (Green)**

Genus CRYPTHEMICHIONASPIS Lindinger

One species only ..... **africana Newstead**

Genus DIASPIS Costa

Key to the adult females

1. Prosoma usually with lateral lobes; L_1 free from inner margins only, forming a deep median notch ..... **boisduvalii Signoret**
   Prosoma without lateral lobes; L_1 free from both margins, not forming a median notch 2
2. (1) Dorsal ducts of pygidium few, nearly as large as the marginal ducts, arranged in a submarginal series ..... **bromeliae (Kerner)**
   Dorsal ducts of pygidium numerous, smaller than the marginal ducts, arranged in submarginal and submedian series ..... **echinocacti (Bouché)**

Genus FIORINIA Targioni

One species only ..... **fioriniae (Targioni)**

Genus FURCHADIASPIS MacGillivray

One species only ..... **zamiae (Morgan)**

Genus ISCHNASPIS Douglas

One species only ..... **longirostris (Signoret)**

Genus LEPIDOSAPHES Shimer

Key to the adult females

1. At least two pairs of pygidial lobes present 2
   Only the median pair of lobes developed, the second pair obsolete ..... **bicuspis Hall**
2. (1) L_2 entire, not bilobed ..... **sacchari Hall**
   L_2 bilobed 3
3. (2) With lateral spurs on the prepygidial abdominal segments 4
   Without spurs 6
4. (3) Dorsal ducts on abdominal segment VI form a continuous group extending from the margins almost to the anus; perivulvar pores numerous, the median pores grouped in a cluster ..... **ulmi (Linnaeus)**
   Dorsal ducts on abdominal segment VI not in a continuous group, but consist of few ducts arranged in one row on the dorsal pygidial area; perivulvar pores few, the median pores arranged in a single short row. 5

5. (4) Thoracic region and first abdominal segment membranous; dorsal ducts few, arranged in submarginal and submedian small groups on abdominal segments II to V, about one or two ducts present on segment VI .... **pallida (Green)**
Thoracic region and first abdominal segment in the fully mature female becomes dorsally heavily sclerotized; dorsal ducts numerous, arranged in distinct segmental rows on abdominal segments I to V, a short submedian row of five or more ducts present on segment VI .... **gloverii (Packard)**

6. (3) With submarginal round bosses on the first two and fourth abdominal segments, one boss on each side of a segment ..... **beckii Newman**
Without bosses 7

7. (6) Median lobes of pygidium moderate in size, rounded, widely separated, the interspace greater than the width of one lobe .... **intermittens Hall**
Median lobes large, notched at ends, relatively close together, the interspace narrow..... **ficus (Signoret)**

Genus PINNASPIS Cockerell

Key to the adult females

1. Dorsal pygidial ducts very few, usually in the marginal area only; abdominal segment IV with one or two submarginal ducts and just mesad of this duct there is a distinct little invaginated pocket, which is usually clearly developed..... **buxi (Bouchè)**
Dorsal pygidial ducts in the marginal area and at least in the submarginal area of segment V; abdominal segment IV with a group of ducts but without any invaginated pocket 2

2. (1) Body almost circular; L_2 indistinct, much smaller than L_1 .... **zillae Hall**
Body elongate; L_2 well developed, bilobed, as large as or larger than L_1 3

3. (2) Median lobes closely appressed together medially, with a distinct median sclerosis (median zygosis) ..... **aspidistrae (Signoret)**
Median lobes not entirely touching each other at the inner margin, without median zygosis ..... **bilobis Newstead**

NOTE: FERRIS' and PRABHAKER'S concept is here accepted and therefore the species *aspidistrae* is considered within the genus *Pinnaspis* Cockerell, not *Hemichionaspis* Cockerell.

Genus PSEUDAULACASPIS MacGillivray

One species only ..... **pentagona (Targioni)**

Tribe ODONASPIDINI

Key to the genera

Adult female

1. — Marginal scleroses marking the intersegmental lines between abdominal segments VI and VII, and segments VII and VIII are commonly present; paratergal areas of segments V and IV and at times of the preceding segments of the abdomen frequently sharply separated from the median ternal areas; perivulvar pores present or absent ..... **Odonaspis Leonardi**
Marginal scleroses between abdominal segments VI, VII, and VIII are not present; paratergal areas not sharply separated from median tergal areas; perivulvar pores absent 2
2. (1) Abdominal segments with sharply defined, transverse, heavily sclerotized bands giving the body a characteristic belted appearance ..... **Osiraspis Hall**
Abdominal segments without such remarkable belted structure ..... **Rugaspidiotus MacGillivray**

Genus ODONASPIS Leonardi

Key to the adult females

a. Anterior spiracles with not more than ten peristigmatic pores; pygidium with marginal sclerosis between segments VI and VII, and segments VII and VIII; dorsal macroducts of pygidium not opening in a thick sclerotized ring, with a diameter distincly less than that of the perivulvar pores ..... **panici Hall**
aa. Anterior spiracles with more than twenty peristigmatic pores; pygidium with marginal sclerosis between segments VII and VIII only; dorsal macroducts of pygidium opening in a thick sclerotized ring, with a diameter equal to that of the perivulvar pores ..... **ruthae Kotinsky**

Genus OSIRASPIS Hall

One species only..... **balteata Hall**

Genus RUGASPIDIOTUS MacGillivray

One species only ..... **tamaricicola (Malenotti)**

Tribe PARLATORIINI

Key to the genera

Adult female

1. Body pupellarial; sclerotic ring around opening of the marginal dorsal macroducts of pygidium, if present, is not conspicuous; antenna with more than one comparatively long setae ..... **Leucaspis Targioni**
Body not pupellarial; sclerotic ring around opening of the marginal dorsal macroducts of pygidium present, and conspicuous; antenna with one comparatively long seta only 2

2. (1) Dorsal marginal macroduct orifices on abdominal segments VII and VIII with associated clavate scleroses; plates tapering apically to a point, not fimbriate, not existing beyond the fourth abdominal segment .... **Parlatoreopsis Lindinger**
Dorsal marginal macroducts without associated clavate scleroses; plates tending to be for the most part short and broad, more or less fimbriate, in a continuous marginal series which extends to and often includes the first abdominal segment ..... **Parlatoria Targioni**

NOTE: Ferris as well as McKenzie, unlike Balachowsky, do not recognise *Parlatoriini* as a separate tribe, but considers it as a part of the tribe *Diaspidini*.

Genus LEUCASPIS Targioni

Key to the adult females

1. Posterior margin of pygidium with four long, tapering, backwardly directed processes, the length of each is about the distance between the base and the anal orifice, with four sclerotized bars behind the level of the anal orifice and four similar bars anterior to this level .. **quadrispinosa Green**
Posterior margin of pygidium without such processes; without such sclerotized bars near the anal orifice. 2

2. (1) L_1, l_2, and L_3 well marked, spiniform, projecting, not confused with the plates; with accessory groups of pores or gland tubercles; plates long, spiniform, equal to each other; perivulvar pores disposed out of the pygidium on the prepygidial segments 3
L_1, l_2, and L_3 faintly marked or wanting, confused with the plates or reduced to small tuberculiform protuberances; without pleuro-ventral parastigmatic pores or gland tubercles; plates long but not equal to each other; perivulvar pores distributed in a single group in an arc. .... **pusilla Targioni**

3. (2) Living on coniferous plants; parastigmatic gland tubercles grouped always in more than ten elements; pygidium normally with three pairs of lobes; fifteen to twenty spiniform plates present external to L_3 (i.e. on segments IV and V) ..... **pini (Hartig)**
Not living on coniferous plants; parastigmatic gland tubercles grouped at maximum in ten elements; pygidium normally with two pairs of lobes; three to four plates at most present external to L_2 (i.e. on segments IV to VI) ..... **riccae Targioni**

NOTE: The species *quadrispinosa* Green is left here in the genus *Leucaspis* for lack of available information about the genus *Mangrovaspis*, in which the species *quadrispinosa* is thought to fit better.

Genus PARLATOREOPSIS Lindinger

One species only ..... **perplexus McKenzie**

NOTE: This species, though recently described as new by McKenzie in 1952, has been existing in Egypt for a long time but under the name *Parlatoria chinensis* Marlatt (or *Chionaspis longispina* Newstead). It is now overspread on different host plants and in various localities of Egypt, even in the Dakhla and Kharga Oases. Hall published about the species under consideration, as used to be named, in 1922 and 1923.

Genus PARLATORIA Targioni

Key to the adult females

1. Eyespot greatly enlarged, appearing as ear-like lobes; shield black .... **zizyphus (Lucas)**
Eyespot either spur-like or lacking; shield never black 2

2. (1) Eyespot spur-like; with derm pocket between posterior spiracle and margin..... 3
Eyespot lacking; without derm pocket 4

3. (2) L_4 membranous and cosely simulating adjacent plates in structure and appearance, although usually much smaller ..... **proteus (Curtis)**
L_4 small, slender, definitely sclerotized and almost spur-like .... **crotonis Douglas**

4. (2) Lobes without notches; duct tubercles lacking. .... **blanchardi (Targioni-Tozzetti)**
Lobers notched; duct tubercles present 5

5. (4) Lobes with sides about parallel, L_1 slightly notched on either side, L_2 and L_3 slightly notched on outer margin, L_4 and L_5 entirely lacking, being replaced by fringed plates; ventral duct tubercles with concave sides, cone shaped ..... **ephedrae Lindinger**

Lobes obviously notched, L_4 and L_5 not replaced by plates; ventral duct tubercles without concave sides, dome shaped 6

6. (5) L_3 and L_4 separated by three lateral plates; L_1, L_2, and L_3 are once notched on each side; perivulvar pores in four groups, reduced in number, the anterior laterals with 3 to 8 pores and posterior laterals with 3 to 6 pores ..... **pergandii Comstock**

L_3 and L_4 separated by four lateral plates; L_1, L_2, and L_3 are once notched on outer margin only; perivulvar pores in four or five groups, more numerous, the anterior median with 0 to 7, anterior laterals with 10 to 29, and posterior laterals with 10 to 21 pores ..... **oleae (Colvée)**

NOTE: Tribe *Xanthophthalmini* which appeared in the preliminary key entitled "Key to the tribes of *Diaspidinae*", is not known to be represented in Egypt.

Subfamily PHOENICOCOCCINAE

The subfamily *Phoenicococcinae* was created by STICKNEY in 1934 for the reception of a single tribe, *Phoenicococcini*, which was also proposed in the same time by the same author. FERRIS, in 1942, preferred not to attempt any division into tribes before a much larger body of knowledge is aquired about this subfamily.

Key to the genera

Adult female

a. Entire body margin and ventrosubmargin covered with numerous promneint papillae; each of two pairs of spiracles with a group of quinquelocular pores; anus situated on ventral surface; a pair of distinct anal-ring setae normally present ..... **Phoenicococcus Cockerell**

aa. Body margin and submargin of both surfaces devoid of papillae; no quinquelocular pores associated with any spiracle; anus distinctly on dorsal surface; anal-ring setae usually absent, if present, inconspicuous or practically so ..... **Halimococcus Cockerell**

Genus HALIMOCOCCUS Cockerell

One species only..... **thebaicae Hall**

Genus PHOENICOCOCCUS Cockerell

One species only ..... **marlatti Cockerell**

SUMMARY

The classification of the scale insects, of Egypt, family *Diaspididae*, is here represented according to the recent concepts in this field. The ideas of MORRISON, FERRIS, BALACHOWSKY, MCKENZIE, STICKNEY, and others are followed to the best available knowledge.

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CONTRIBUTIONS TO THE BIOLOGY AND BIOCHEMISTRY OF THE COTTON LEAF-WORM, *PRODENIA LITURA* F.

III. THE MORPHOLOGY AND HISTOLOGY OF THE SEXUAL SCENT GLANDS IN THE FEMALE MOTH OF *PRODENIA LITURA* F.

[*Lepidoptera: Agrotidae-Zenobiinae*]

(with 5 Text-Figures and 1 Table)

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CONTENTS

I. Introduction. — II. Methods and technique. — III. Morphology and histology of the sexual scent glands. — IV. Discussion. — V. Summary. — VI. Acknowledgments. — VII. References.

I. INTRODUCTION

In the course of the chemical experiments on the sexual scent glands of the cotton leaf-worm *Prodenia litura* Fab. (FLASCHENTRÄGER, EL-SAYED AMIN and JARCZYK, 1957), it was found necessary also to study the morphology and histology of these scent organs. As a matter of fact these authors proved experimentally the presence of the scent organs in the last two abdominal segments of the female moth.

In Lepidoptera, scent organs are known to occur in males as well as in females. These organs are supposed to bring the two sexes together for fecundation (GÖTZ, 1951). The females, however, are able to attract the males from considerable distances by means of the scent secreted by these scent glands.

The scent producing organs of the male consist of tufts of glandular scales or hairs on the abdomen (DICKINS, 1936), on the legs (ILLIG, 1902), or on the wings (ILLIG, 1902; FREILING, 1909). The female scent glands are always found in the neighbourhood of the sexual openings at the posterior end of the abdomen, mostly between the 8th and 9th abdominal segments. Histologically, the female scent organs are all more or less identical in structure. They take the form of tufts of modified scales or hairs with gland cells at their base, or a simple fold in the body wall consisting of a vacuolated glandular epithelium covered by thin cuticle (WIGGLESWORTH, 1953). Special secretory ducts in these glandular epithelial cells have not yet been proved for certain, but it is supposed that the secretion leaves through pores in the thin cuticle covering these scent organs (BARTH, 1937).

II. METHODS AND TECHNIQUE

The male and female moths, used in this work, were obtained from a culture which was succesfully bred in the laboratories of the Biochemistry Department, Faculty of Medicine, Alexandria University, from March until April, 1957.

Serial cross, logitudinal and horizontal sections in the abdomen of the moths were made. These moths were fixed in hot BOUIN's fluid for about 24 hours. They were then dehydrated and kept in terpineol for about 2-3 weeks. The specimens were then treated with benzol, 3 changes for about 10-15 minutes each being used. The material was then placed in a mixture of soft paraffin wax (46-48°C.) and benzol (1:1) for about one hour, then removed to three changes of soft wax (56-58°C.). The vacuum pump was used from time to time during embedding in the wax. Sections were made at a thickness of 8-10 μ stained with EHRLICH's or DELAFIELD's haematoxylin and counterstained with eosin.

III. MORPHOLOGY AND HISTOLOGY OF THE SEXUAL SCENT GLANDS

In the female, there is a characteristic tuft of modified scales, which will for convenience be called hairs (h), covering the whole surface of the 9th abdominal segment (Fig. 1, A,C,E). Each hair is thin and smooth, and being about 1,5-2 mm. long and about 2 μ in cross-section (Fig. 1, A,C,E; and Fig. 3, B). In the resting period, this 9th segment is invaginated into the 8th one as shown in the Figures.

Serial sections of the female abdomen (Fig. 2 A, and Figs. 4 and 5), show evidently that here is no sexual scent organ situated between the 8th and 9th abdominal

segments in constrast with the usual case in most of the female moths where the scent organ is always situated in the intersegmental membrane between the 8th and 9th abdominal segments. They also show that the epidermal cells of the 9th segment are much larger in size than those of the other segments. In this 9th segment,

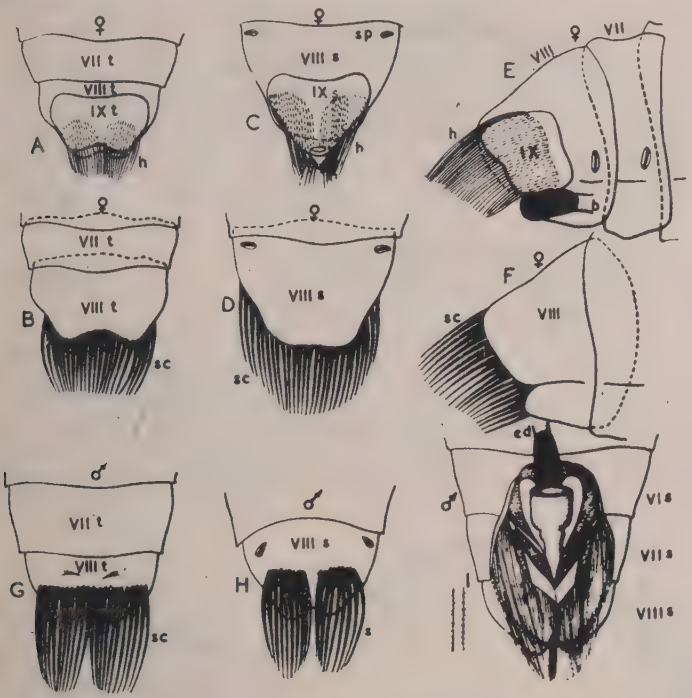

FIG. 1: In A, C, E, I, all ordinary scales covering the whole body have been ommitted for simplicity. In B, D, F, G, H, only scales (sc) on the posterior margin of the 8th abdominal segment are shown.

A, Inner view of last abdominal tergites of female, with the modified tuft of hair (h) on the 9th segment. — B, Outer view of same without the 9th segment (for simplicity). — C, Inner view of last abdominal sternites of female. — D, Outer view of 8th sternite of female. — E, Interno-lateral view of last abdominal segments of female. — F, Externo-lateral view of same. — G, Dorsal view of last abdominal tergites of male. — H, Ventral view of 8th sternite of male. — I, Inner view of last abdominal sternites of male with the genital organs. Some structures of the latter have been ommitted for simplicity (on the left, notice an enlarged part of a modified scale of the male claspers). — b, bursa copulatrix; cl, clasper; ed, ejaculatory duct; h, modified tuft of hair; sp, spiracle; VII-IX, 7th-9th abdominal segments; VIs-IXs, 7th-9th abdominal sternites; VIIt-IXt, 7th-9th abdominal tergites.

each cell is more or less columnar or cubical spongy in appearance, being about 20-30 μ high and with a rounded nucleus of about 10 μ in diameter. The cell rests, as usual, on a basement membrane and the cell boundaries are distinct. Some of

these cells of the 9th segment are gigantic with an usually large nucleus. The cuticle covering these large epithelial cells is thin, being about 7-8 μ in thickness. The epithelial cells of the 9th segment are richly supplied with tracheae (Figs. 3, 4, 5, tr.) and they are, without any doubt, glandular owing to the presence of oil-like droplets

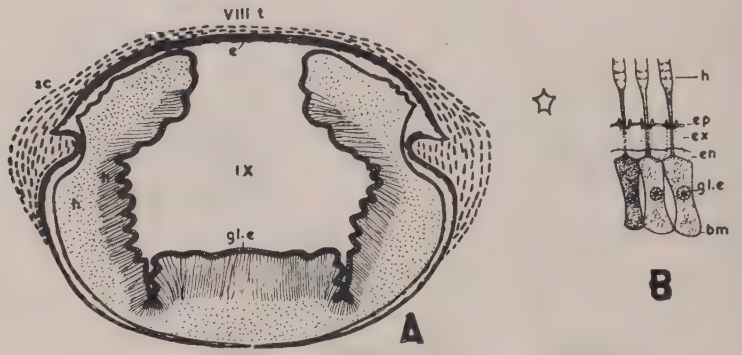

FIG. 2 : A, Oblique section of 8th and 9th abdominal segments of female (simplified), missing the postero-ventral margin of the 8th segment and the antero-dorsal margin of the 9th segment. — B, Three enlarged cells of the glandular epithelium of the 9th abdominal segment of female (3 days old). Notice the cross-section of a modified hair on the left. — bm, basement membrane; e, epithelium; en, endocuticle; ep, epicuticle; gl.e, glandular epithelium. — For other lettering, see Figure I.

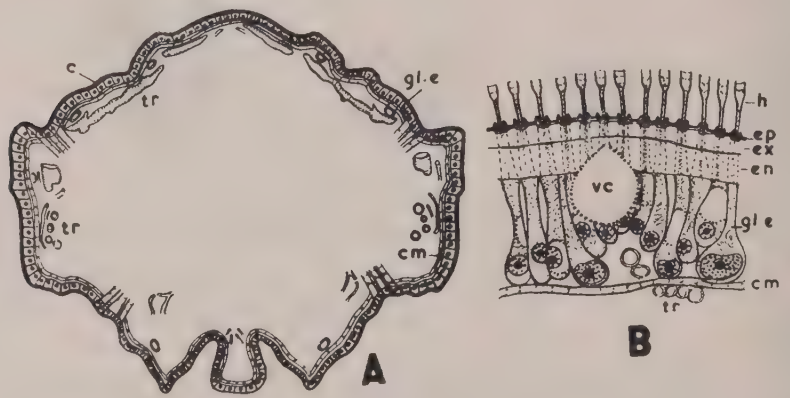

FIG. 3 : A. Transverse section of 9th abdominal segment of female. Modified hairs omitted for simplicity. — B. Some active cells, 1-2 days old, of the glandular epithelium of this 9th segment. — c, cuticle; cm, circular muscle bands; tr, tracheae and air-sacs; vc, oil-like droplets of secretion. — Other lettering as in previous Figures.

of secretion (vc) in both the gigantic and the other smaller cells. Large droplets of the oil-like secretion are seen each covering more than one cell and at the same time penetrating the overlying cuticle. No special secretory ducts in these glandular epithelial cells are observed.

From each glandular cell there grows one of these long hairs of the 9th segment (Figs. 2 B, and 3 B). The plasmatic outgrowth of the cell is seen clearly having the same stain of the cell itself, penetrating the cuticle to the base of the hair. The latter is thinner basally towards the insect cuticle.

Serial sections of the females were made at the ages of 1 hour, 1 day, 2 days, 3 days, 4 days and 5 days (before egg-laying), respectively. Also, similar sections were made in females 5 days old after laying eggs. These sections show that in the first and second days old females, the glandular cells of the 9th abdominal segment are larger than in the 3-5 days old females as shown in Table I.

TABLE I

Age of female	Glandular cells	
	Shape	Height in μ
1 Hour	Columnar	About 20
1 Day	Columnar	,, 20
2 Days	Majority columnar and few cubical	,, 20
3 Days	Majority cubical and few columnar	,, 15
4 Days	Cubical	,, 10
5 Days (before egg-laying)	Cubical	,, 10
5 Days (after egg-laying)	Cubical	,, 7,5

It is seen from the above Table that after the second day, the glandular cell of the female moth starts to shrink and decrease in size. Therefore, the best age for collecting female moths for the chemical extraction of the scent material is that of the 1-2 days old females.

In the male, there are fine modified scales similar in general appearance to the tuft of hairs of the female moth. These modified scales of the male are present on the claspers of the male genitalia (Fig. 1, I), and each being about 2 μ in diameter and covered with very fine hairs as shown in Figure 1, I. No glandular epithelial cells were found lying underneath such scales.

IV. DISCUSSION

According to EIDMANN (1929), the sexual scent organs are always present on the female abdomen and they are most developed among female moths in which the eggs are ripe for laying at the time of emergence from the pupa. Such moths have usually a short life.

The scent organ of *Phalera bucephala*, in its simplest form, consists merely of a simple saddle-shaped "field" in the last inter-segmental membrane between the 8th and 9th segments (URBAHN, 1913). When stretching the abdomen, the inter-

segmental fold is simultanously stretched to the outside and therefore the scent organ comes into action.

An annular or ring-shaped scent gland is found in *Pygaera pigra* and *Pygaera curtula* and forms a completely closed ring of glandular epithelium in the intersegmental fold between the 8th and 9th segments (GÖTZ, 1951). In the more developed scent rings, the glandular epithelium of the abdominal fold between the 8th and 9th segments is strongly enlarged and is deeply invaginated inside the body cavity. Both ring folds of the scent glands are evaginated, for better evaporation of the sexual scent, by means of the blood pressure. The deep ring-shaped scent glands are represented in the Noctuids *Cucullia verbasci* and *Cucullia argentea* (URBAHN), although GÖTZ claims that they are found most probably in all Noctuid females.

Specific scemt glands are formed by the enlargement of the dorsal or ventral glandular epithelial cells of the last inter-segmental fold. As for the dorsally situated scent glands, they occur in *Hypogymna morio*, *Dasychira selenitica* and *Dasychira pudibunda* (URBAHN), whereas the ventral ones are found in *Plodia interpunctella* (BARTH). In these specific scent glands, the female, which is ready for copulation, stretches the 9th abdominal segment vertically upwards and eventually stretching the last inter-segmental membrane, where the dorsal or ventral glands are situated, thus exposing the scent glands to the surface (MÜLLER, 1938).

By local surface enlargement of the epithelial cells of the last inter-segmental fold, the scent sacs "sacculi laterales" are formed. These sacs are evaginated by the females when these females are ready for copulation (GÖTZ). The scent sacs are formed either singly or in pairs on each side of the body. They are also situated either dorsally or ventrally and they are withdrawn by means of special muscles. The scent sacs are found in *Bombyx mori*, *Argymnis paphia*, *Saturnia pavonia* and *Brenthis euphrosyne* (URBAHN).

The "glanduli oliferae" are originated by the transformation of the last inter-segmental fold to a pair of glandular hoses, which travel deep into the cavity of the 8th abdominal segment, on both sides of the body. These hoses are found in *Vanessa urticae*, *Acronycta psi* and *Argymnis paphia* (URBAHN).

In the present work, it is found that the 9th abdominal segment of the female moth *Prodenia litura* is completely covered by glandular epithelium which is slightly enlarged laterally (Fig. 3, A). Also, a special modified tuft of scales (hairs) is seen covering this 9th segment (Figs. 1, A, C, E; 2 A; 3, B, 4 and 5, h). These hairs have, undoubtedly, the function of increasing the evaporating surface of secretion. The glandular epithelium is at its largest size and activity in the first two days after the emergence of the female moth. Then, it decreases gradually in size as the female grows older (Table I). There are also longitudinal muscles (Figs. 4 and 5, lm) attached to the anterior end of the 9th segment. On the contrary, no glandular epithelium was found in the male moth of *Prodenia litura*.

The cells in the glandular epithelium of *Prodenia litura* are well developed in the 1-2 days old female moth. Some of these cells are rather gigantic with an unsually

large nucleus. Both gigantic and smaller cells have secretion, which is seen covering more than one cell and also leaving the cuticle to the outside (Fig. 3B). After the secretion of the scent during the first two or, maybe, three days of the female moth's life, the glandular epithelium shrinks and decreases in size (Fig. 2B). It was also observed, as shown in the Figures 2B and 3B, that each epithelial glandular cell has a hair grown from it. Each hair is thinner basally where it joins the cuticle.

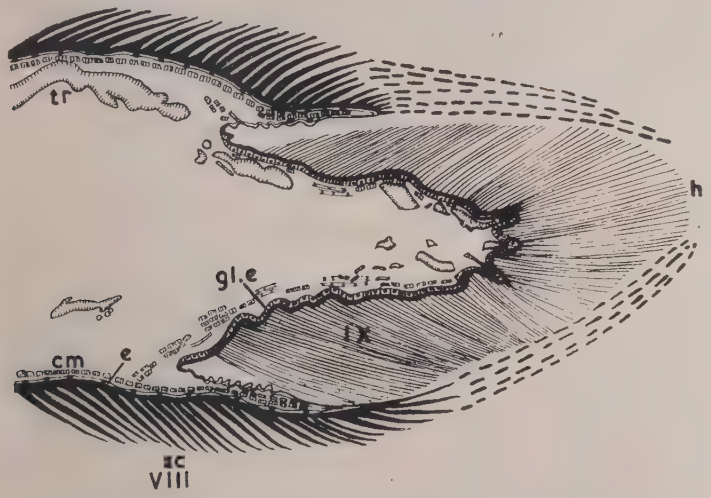

FIG. 4 : Horizontal section of 8th and 9th abdominal segments of female (simplified). Lettering as in previous Figures.

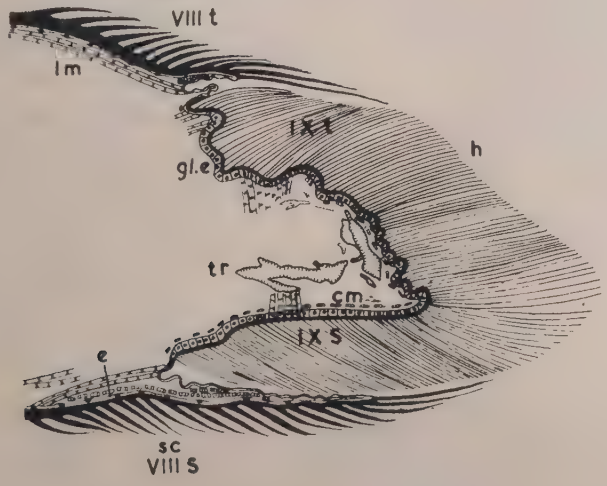

FIG. 5 : Longitudinal section of 8th and 9th abdominal segments of female (simplified). lm, longitudinal muscle bands. — Other lettering as in previous Figures.

From all these observations, it may be supposed here in *Prodenia*, that the secretion of many cells is gathered, at the time of activity of the scent organ, in large droplets of secretion for leaving to the outside. The hairs, being thinner towards the cuticle, allow larger space for the exit of the secretion droplets, which will then spread over the hair surfaces for better evaporation. The presence of strong longitudinal muscles attached to the anterior end of the 9th segment of *Prodenia litura* (Fig. 5, lm) is, maybe, of use to the pulling in of this segment, which maybe also pushed out by the concentrated circular muscles around the anterior end of the 9th segment (Figs. 4 and 5).

However, it is certain that there is no similarity in form or position between the sexual scent organs of *Prodenia litura* and those described by GÖRZ in other Noctuidae.

V. SUMMARY

1. — The morphology and histology of the sexual scent organ of the female moth of the Cotton Leaf-Worm, *Prodenia litura*, is described in detail.

2. — Only the ninth segment of the female is completely covered with glandular epithelial cells, which have fine hairs attached to it. On the contrary, no glandular epithelium was found in the male abdomen.

3. — In the normal condition, the 9th segment of the female is contained wholly within the 8th segment. During the secretory period, this segment is pushed to the outside by means of circular muscles.

4. — The histology of the secretory epithelial cells of this 9th segment is studied. Also, the structure of the fine hair is described.

5. — The secretory epithelium is at its largest size and highest activity in the first two days after the emergence of the female moth and then it shrinks gradually as the female grows older.

6. — No special glandular ducts are seen, and therefore the secretion may penetrate through the cuticle. It means that the molecule of the female sex-attractant should be small.

7. — It is found that the scent organ of *Prodenia litura* is not typical, as described by other authors for other Noctuidae.

VI. ACKNOWLEDGMENTS

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NOTES ON THE MAGNITUDE AND VERTICAL DISTRIBUTION OF MYRIAPODA IN CULTIVATED SOIL

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I. INTRODUCTION

In cultivated land, some of the myriapods are considered as beneficial factors while others act as serious pests. ROMELL (1935), JACOT (1940) and SALT (1922-et al. (1948) refer to millipedes as humus- or mull-forming animals. Their status among other soil arthropods is illustrated by BUCKLE (1921), MORRIS (1922-1927), THOMPSON (1924), EDWARDS (1929) and BAWEJA (1939).

The distribution of chilopods and diplopods in Britain as well as their response to physical environment and their role in forest soils are discussed by BLOWER (1955). The economic importance of these animals in arable and grass land is shown by CLOUDSLEY-THOMPSON (1950).

Several aspects concerning Symphyla are discussed by MICHELBACHER (1938), MARTIN (1948), STANILAND and STONE (1951) and EDWARDS (1955). Biological and ecological studies of some symphalid species were achieved by FILINGER (1928), MICHELBACHER (1938 and 1939). STARLING (1944) made some ecological studies on Pauropods and KÜHNELT (1955) gave a brief note about their function in the soil. SEARLS (1928) and EDWARDS (1955) showed methods for rearing animals of Symphyla and Pauropoda

The present work illustrates the magnitude and vertical distribution of Myriapoda in the soil of the farm of the Faculty of Agriculture at Giza, Egypt.

II. METHOD

The period of investigation in this work covered a whole year, starting from April 1951 until March 1952, and the method used was as follow :

1. — Six fields were selected for examination; four of them were of light clay soil, the other two were of clay loam.

2. — From each field a hundred samples were taken at random, five samples at a time during different months of the year.

3. — The size of a sample was four inches in diameter and fifteen inches deep below the soil surface. The soil obtained was then divided into four strata, viz: 0-3, 3-6, 6-10 and 10-15". Similar strata taken at a time were bulked together.

4. — Extraction of the fauna was carried out by SALT and HOLLICK's flotation method (1944).

To show the more suitable method for extracting the soil myriapods, the following trial was, carried out:

1. — Fifteen pairs of samples of the same size described before were taken at random from a fallow clay loam field in March 1956. Another twenty pairs of samples were taken from a clay loam field under onion in April 1956.

2. — One sample of each pair was treated by the TULLGREN-funnel method and the other by the flotation method for purpose of comparison. Estimation of the fauna by the former method was done after 24 hours from putting the sample in the funnel.

N.B. — The meteorological conditions of the district, the history of the fields examined (designated by the letters A to F in the Figures) together with their mechanical analysis and botanical censuses are all recorded in another paper by the writer (1957).

III. RESULTS AND DISCUSSION

In the course of the present investigation, no members of the order Pauropoda or Diplopoda were met with by sampling, denoting the scarcity or absence of these forms in the soil of the fields of experiment. Chilopoda and Symphyla occurred in varying numbers as will be illustrated hereafter.

Myriapoda, as a whole, formed a small fraction of the total soil arthropod fauna. The mean per acre per annum varied considerably, according to the kind of soil, being in general lower in light clay soils than in clay loam soils (Fig. 1). In light clay soils the mean per acre per annum ranged from 20.000 to 160.000 specimens and in clay loam soils from 290.000 to 330.000 specimens. The percentage of myriapods in the total number of Arthropods found in the examined soils, varied from 0.18 to 1.79% in light clay soils and from 4.59 to 6.64% in clay loam soils. Although the means per acre per annum of both Chilopoda and Symphyla were higher in clay loam soils than in light clay soils, yet the percentage of Symphyla was higher in the latter soils than in the former (Fig. 1). This means that chilopods in general were in greater number than symphalids in light clay soils while the reverse occurred in clay loams. Percentages of chilopods, in the total number of myriapods, ranged from 57.69 to 75% in light clay soils and from 40.91 to 43.10%

in clay loam soils. Percentages of symphalids ranged from 25 to 42.31 % in the former type of soil and from 57.90 to 59.31 % in the latter type.

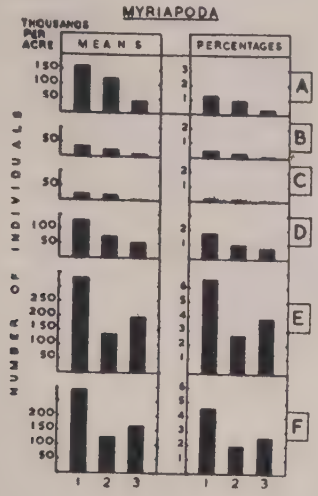

FIG. 1: Myriapoda (faunal means per acre per annum and percentages in total Arthropod fauna) : (1) Total Myriapoda; (2) Chilopoda; (3) Symphyla; (A to D) fields of light clay soil; (E and F) fields of clay loam soil.

The mean number of myriapods and of each of its components under various rotational periods were found to fluctuate under various crops or fallows, and also from field to field under the same crop (Fig. 2). In field (B) and (C), the animals were either missing or found in few numbers, because these two fields remained dry for long time under wheat or fallows. Field (A) and (D) had higher counts because they were relatively more irrigated. In the four fields and under the same crop of berseem (clover) the counts were found to fluctuate considerably because of the different rotation or agricultural operations adopted. In field (A), berseem did not receive any kind of manure, while it received superphosphate in fields (C) and (D).

In fields (E) and (F) of the clay loam soils, the means though relatively higher, yet the fluctuations were also obvious. The maximum number of myriapods per acre was 600.000 specimens in light clay soils under fallow (field D) in October 1951 and 1.400.000 specimens in clay loam soils under cabbage (field E) in December 1951.

A conception of the vertical distribution of myriapods is illustrated in Figure 3. The animals were missing in the three-inch surface layer in the light clay soils, but existed in variable numbers in the same stratum in clay loam soils. The scarcity of animals in the next three-inch stratum was also noticed in light clay soils than in clay loam soils. Myriapods seemed to prevail in the undisturbed layer

between 6 and 15 inch below the soil surface; but in field (F) they tended to prevail in the ten-inch surface layer and this might be due to the shade and continuous irrigation of the pear trees which regulated the summer temperature. On the other hand, the missing of myriapods in the six-inch layer in field (B) and (C) might be

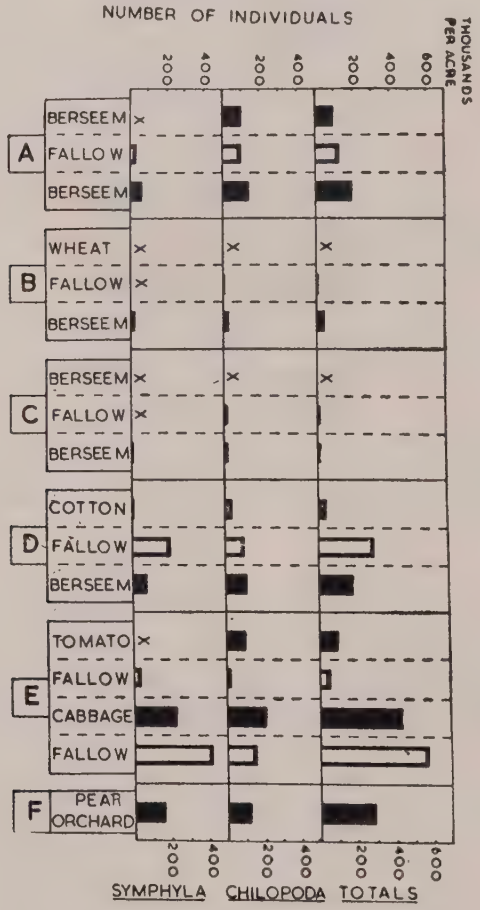

FIG. 2: Myriapoda (faunal means per acre under various rotational periods): (A to D) fields of light clay soil; (E and F) fields of clay loam soil.

due to dryness and intense summer heat. Myriapods were found to penetrate to fifteen inches below the soil surface (Fig. 3). Sampling down to thirty inches below the soil surface in November 1951 showed that myriapods could be found at that depth. FILINGER (1928) showed that the garden centipede, *Scutigerella immaculatus* Newport penetrated to a depth of 18-36 inches during summer to oviposit.

Samples obtained during various seasons of the year showed that myriapods were much affected by temperature and dryness of the soil during summer. During this season, the animals were either scarce or totally absent, especially in the surface strata. Their migration to the upper stratum which occurred only in clay loam soils, happened in other seasons. In the soil of the pear orchard (field F), the samples contained myriapods during all months of the year, except for July and August which are the hottest months. In field (C) that remained dry during summer fallow, myriapods were missing during most months.

FIG. 3: Vertical distribution of Myriapoda: (A to D) fields of light clay soil: (E and F) fields of clay loam soil.

Of the 49 specimens obtained from the fallow area in March 1956 and extracted by both the TULLGREN-funnel method and flotation method, 19 of them (38.8%) were extracted by the funnel method and 30 of them (61.2%) by the flotation method. The flotation method also proved superior over the funnel method in extracting myriapods from soil under onion; 22 specimens (61.1%) out of 36, extracted by the two methods, were caught through the flotation method. This suggest that the flotation method might prove more efficient than the funnel method in extracting soil myriapods.

The specimens of Chilopoda obtained in the present work (from April 1951 to the end of March 1952) belong to the genus *Geophilus*. Ninety-nine specimens that belong to this genus were extracted from 600 samples obtained from the six fields. The maximum number per acre obtained was 400.000 chilopodes in light clay soils (in field A in October 1951, and in field D in January 1952), and 500.000 in clay loam soils (in field F, in April 1951).

The specimens of Symphyla obtained belong to the genus *Scutigerella*. Ninety-four specimens that belong to that genus were extracted from 600 samples obtained from the six fields. The maximum number per acre obtained was 400.000 symphalids in light clay soils (in field D, in October and November 1951) and 1.100.000 in clay loam soils (in field E, in December 1951).

IV. SUMMARY

1. — Myriapods were extracted from light clay and clay loam soils. They

formed a small fraction of the total soil Arthropods. They were more in number in clay loam soils than in light clay soils.

2. — Means per acre per annum in six fields and means under various rotational periods are illustrated. The vertical distribution of myriapods is discussed. Dryness and temperature affected greatly the number and distribution of the animals.

3. — The flotation method for extracting the soil myriapods (especially symphalids) proved, in most cases, superior over the funnel method.

4. — Chilopoda and Symphyla were the only two groups met with in the two types of soils studied. Chilopoda was represented by the genus *Geophilus* and Symphyla by the genus *Scutigerella*.

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ANTS, THE PROBABLE AGENTS OF THE ONSET OF INFESTATION OF COTTON WITH APHIDS AND COCCIDS

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From the middle of April to the end of May 1956, the plants in an experimental cotton field at the Entomological Field Station, Giza (Cairo), were examined every day. No aphids or coccids were found on them before the 10th of May. But on that day, first-instar nymphs of the cotton aphid, *Aphis gossypii* Glover, and of the coccid *Phenacoccus hirsutus* Green, were found on many of the plants (now about 5 in. high). The field was laid out in sixteen plots containing seven rows of five plants each, the plots being separated by raised banks. In each plot the aphid and coccid nymphs were found on nearly all the outside plants and on some of the next plants in from the ends of the interior rows, but practically none on the middle plants. The two types of nymphs were found on the lower surfaces of leaves or on the stems : singly in most cases, although occasionally one aphid and one coccid were found close against each other in the angle between the mid-rib and a vein of one leaf.

No adult coccids or aphids, and no older nymphs, were found in the course of a thorough search of the cotton and other neighbouring plants; nor had the weather been windy enough to warrant any suspicion that the nymphs might have been blown into the field. From the first day, however, about 95% of the nymphs of both types were busily attended by the garden ants, *Monomorium gracillimum* and *Monomorium atomus* Don. These ants were seen active on the ground between the plots and among the outside plants of the plots, but rarely inside the plots, both before and after the nymphs appeared.

This combination of circumstances made it difficult to suggest any means by which the aphids and coccids could have reached the plants, other than being carried and placed there by the ants. It is known that certain ants do collect the eggs of stem and root aphids and coccids, store them in their nests over the winter, and transport the newly-hatched nymphs to host-plants in the spring (NIXON, 1951).

It was also shown that the coccid *Saissetia zanzibarensis* Williams is dependant on the ant *Oecophylla longinoda* Latr. for its protection and transportation to suitable feeding sites and is rare in its absence (Way, 1954).

Recent findings (unpublished data) showed that the root aphid *Triphidaphis phaseoli* Theo. on bean roots depended on the ants *Paratrechina jaegerskjoeldi* Mayr and *Plagiolepis pallescens* Forel for its transportation and dissemination from plant to plant and from one crop to another which may also be a supporting evidence.

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A BRIEF NOTE
ON THE ARTHROPOD FAUNA OF A BIRD NEST

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On the 2nd of June 1957, while the writer was walking near the fence of the Faculty of Agriculture (Cairo University), he saw a bird nest which had been fell under a tree, *Ficus mangifera*. The nest was moderately large. It was made up of bird feathers, plant roots and stems, strings, rotten pieces of cotton and rice straw. Inside the nest there was a killed sparrow whose internal viscera and muscles were completely eaten. This denoted that the nest belonged to a carnivorous fierce bird. Numerous ants were invading the nest, showing that it felt some hours before as it was not present under the tree the day before.

When taken to the laboratory, the nest, with the sparrow inside, was treated by the Tullgren-funnel method for five days during which the fauna extracted was examined daily.

The mite fauna was so great that the first catch (after the first 24 hours) contained too many specimens that it was almost impossible to count them one by one. Thus, they were all transferred to a graded test tube where water was added to reach 100 cc. After shaking thoroughly, 5 cc. were taken off and the mites they contained were examined and estimated. This was repeated for three times and the whole mites existing were deducted. The fauna in other catches was easily estimated. Estimation of the insect fauna was carried out at first.

When the faunal extraction ended, the nest together with the sparrow weighed 126 grams, of which 3.4 grams only represented the weight of killed sparrow.

Excluding the ants, the total arthropod fauna extracted reached 3571 specimens (20.4 per gram) of which 24 specimens (0.2 per gram) were insects and the rest (20.2 per gram) were mites which composed 99.3 % of the arthropods found in the nest. They were all Mesostigmatid mites, of which a Dermanyssid species was prevailing. Of the 24 insects met with, 18 specimens represented *Leptocelis diverticulus* (Psocoptera), four dipterous flies (two Mycetophilid and two Muscoid) and two lepidopterous larvae.

THE RELATION OF *MUSCA SORBENS* WIED. TO EYE DISEASES, IN EGYPT

[*Diptera*: *Muscidae*]

(with 3 Text-Figures and 5 Tables)

by MAHMOUD HAFEZ, M.SC., PH.D., F.R.E.S.,

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The fact that *Musca sorbens* breeds in nature almost exclusively in human excrement (HAFEZ and ATTIA, 1958a) and frequents other contaminated situations such as wounds, ulcers, sores, etc., adds a great deal to the potentiality of this fly as a possible vector of enteric infections and other diseases.

The review of the literature reveals the importance of *M. sorbens* from the medical point of view in various countries. This fly has been incriminated as the transmitter of several diseases such as ophthalmia (PATTON 1919, in Mesopotamia), bacillary desentery (PATTON 1919, in Mesopotamia; OMAN and CHRISTENSON 1947, in South Pacific), amoebiasis (AUSTIN and MAYNE 1935, in Nyasaland; HARRIS and DOWN 1946, in Guam); leprosy, tuberculosis and *Trypanosoma rhodesiense* (LAMBORN 1935-1940, in Nyasaland), and yaws (SATCHELL and HARRISON 1953, in Western Samoa). In North Africa (Mo occo), GAUD et AL. (1954) studied the habits of *M. sorbens* and expressed the opinion that owing to its persistent settling on the human body particularly near the eyes, nose and mouth, it is a more likely vector of ocular and intestinal infections and of poliomyelitis. They further added that when anti-fly campaigns were extended to yards and other open areas, they had a marked beneficial effect on acute conjunctivitis.

In Egypt, however, the possibility of the significant role that *M. sorbens* is playing in relation to diseases has not been fully assessed. However, in 1935 the occurrence of this fly on diseased eyes in greater numbers than *M. vicina* was reported by the Research Institute of Endemic Disease, Cairo. More recently BAKRI

(1955) and De Coursey et Al. (1956) also collected the fly from diseased eyes. The medical importance of *M. sorbens* has been greatly emphasised by West (1953) in his recent report on "Fly control in the Eastern Mediterranean and elsewhere" and suggested that this fly might be acting as a potential vector of eye diseases and was inclined to believe that, in so far as flies may be involved in the transmission of either conjunctivitis or trachoma, *sorbens* rather than *vicina* is probably the species largely concerned. In his report, West also expressed the urgent need for thorough investigations on this fly. Since then, more attention has been focussed on *M. sorbens*, and its possible relation to eye diseases has been studied both ecologically and bacteriologically. The former aspects (field investigations) were undertaken by the present authors while the latter by De Coursey and his co-workers at the Naval American Medical Research Unit, Cairo. The results of the latter authors appeared in 1956.

In the present paper, which is the third in a series on *M. sorbens* in Egypt (Hafez and Attia, 1958 a and b), three points were investigated : (a) fly catches on diseased eyes, (b) the seasonal abundance of *M. sorbens* and the incidence of ophthalmiasis, (c) the degree of prevalence of both *sorbens* and eye diseases in districts with no drainage system of sewage disposal and where defecation in the open commonly occurs. Whether the attraction of the fly to diseased eyes is an olfactory response or a moisture reaction has been also experimentally demonstrated.

OBSERVATIONS AND EXPERIMENTS

From preliminary observations made on diseased eyes of children in Talbia village during 1954-1955, it was found that the flies most frequently alighting on the eyes of these children were of two species, *M. sorbens* and *M. domestica vicina* (Hafez and Attia, 1958a). They were most attracted to eyes, producing a discharge, and sometimes were seen "shoulder to shoulder" on the margins of the eye lids.

Weekly catches of flies from the eyes were then made throughout the year and the relative numbers of both species were recorded.

The data (Table I) showed clearly that the numbers of *M. sorbens* alighting on the eyes differed according to the season of the year. It predominated in the spring, summer (August) and autumn (October). In three months (March, April and June) over 80% of the flies caught on the eyes were *sorbens*, in three other months (February, May and August) over 70% were *sorbens* while in October about 55% of the flies collected from the eyes were again *Musca sorbens*.

M. domestica vicina, on the other hand, was more abundant and outnumbered *sorbens* in November-January where it constituted 80% on an average, of the number of flies caught on the eyes. Nearly similar findings were reported by De Coursey et Al. (1956). These authors found that *vicina* predominated on faces from December through March and *sorbens* from April to July.

TABLE I

Monthly mean counts of Musca sorbens *Wied. and* Musca domestica vicina *Macq. on diseased eyes in 1954-1955.*

Month	Mean monthly counts			
	sorbens		*vicina*	
	Number	%	Number	%
November 1954	40	9.6	375	90.4
December 1954	76	18.4	334	81.6
January 1955	90	32.8	246	67.2
February 1955	132	68.7	58	31.3
March 1955	109	80 5	25	19.5
April 1955	176	83 0	36	17.0
May 1955	116	71.6	26	28.4
June 1955	114	88.4	15	11.6
July 1955	62	45.2	75	54.8
August 1955	124	71 3	50	28.7
September 1955	58	36.5	101	63.5
October 1955	92	55.4	74	44.6

Comparing the abundance of *M. sorbens* in nature (Fig. 1) with the numbers of the same species that were attracted to diseased eyes, we find that the numbers caught on the eyes generally reflected the population level during the year. The data showed that the fly population peak of *M. sorbens* in nature occurred during the spring (April and May), summer (August) and autumn (September).

TABLE II

Out patients, Children's Department (Hospital), classified monthly during 1953.

Date	New patients			Old patients			General total
	male	female	total	male	female	total	
January	469	385	854	391	349	740	1594
February....	316	250	566	260	235	495	1061
March	294	255	549	264	248	512	1061
April	548	486	1034	408	369	777	1811
May	1984	1771	3755	1167	1032	2199	5954
June.....	1814	1567	3381	1108	1076	2184	5565
July	1873	1612	3485	1156	977	2153	5638
August	837	691	1528	578	500	1078	2606
September	1013	815	1828	712	626	1338	3166
October.....	1032	808	1912	720	624	1344	3256
November	699	601	1300	645	560	1205	2505
December .	328	303	631	232	211	443	1074

The incidence of the eye diseases was studied at the University Children Hospital, Cairo, and the records of several years were inspected. Figures 2 and 3 were constructed from the data obtained in 1953 (Table II) and 1954 (Table III) and represent samples of the seasonal prevalence of ophthalmiasis. The Figures and Tables clearly demonstrate that the occurrence of the disease reached a peak in the spring, summer and autumn. This is markedly correlated with the peaks of

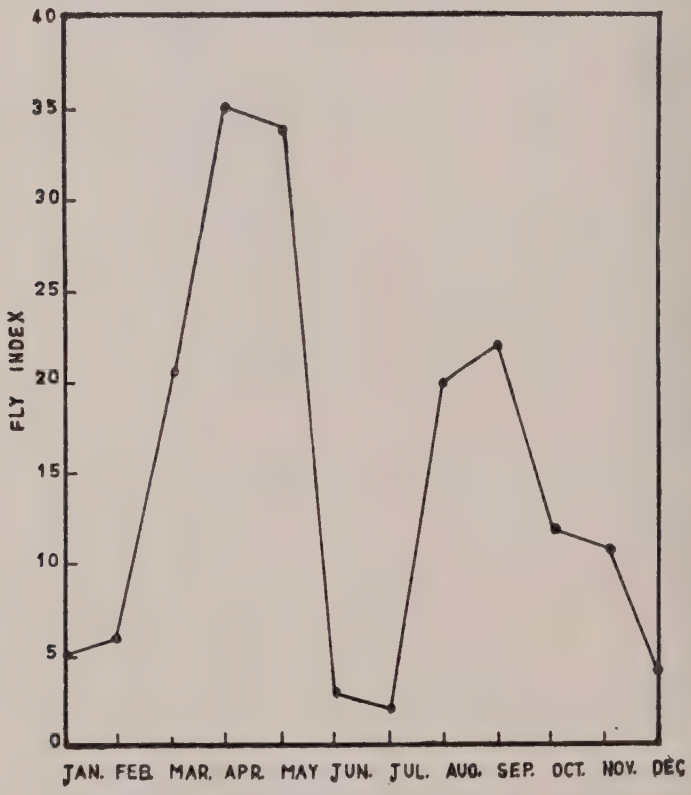

FIG. 1: Fly index of *M. sorbens* throughout the year 1954.

abundance of *M. sorbens*, that were either attracted to eyes or those found in nature. In winter, e.g. December and January, on the other hand, the disease was of less occurrence which was also accompanied by a marked decrease in the numbers of *M. sorbens* and an increase in the number of *M. domestica vicina* attracted to the eyes (Table I). This may indicate that the latter species in this season of the year and probably in other seasons does not play an important part in the dissemination of eye diseases.

It was further found that in those districts where eye diseases are of common occurrence, the sewage disposal system is still in a primitive condition, defecation takes place mostly in the open, thus providing suitable breeding media and adding to the population of this fly in such districts (e.g Old Cairo, Giza and Gayyara).

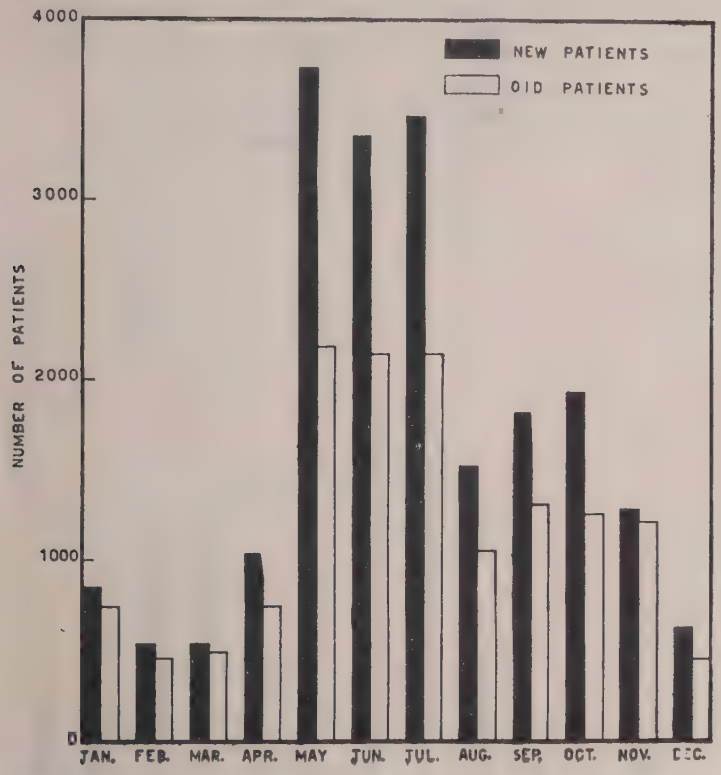

FIG. 2; The incidence of ophthalmiasis during the year 1953, constructed from data available at the University Children Hospital, Cairo.

In districts with adequate sanitation (e.g. Kasr El-Nil and Manial), however, the flies and the eye diseases are of lesser occurrence. Thus in either case a marked correlation was found between the incidence of eye diseases in these districts and the population density of *sorbens* using SCUDDER'S grill (Table IV).

Laboratory investigations were also carried out to assess the attraction of *M. sorbens* to pathological secretions of diseased eyes and the reactions involved. Small dishes containing secretions from diseased eyes and others neutral (controls) were introduced into cages containing *M. sorbens* after being covered with wire screens. Most of the flies in the cages frequently visited the dishes containing the

secretion. Very few flies settled at random on the other dishes. Similar results were also obtained when two pieces of cotton wool were used; one was soaked in water while the other was contaminated with secretions from diseased eyes. Most of the flies congregated on the second piece of cotton wool where they were noticed feeding actively.

The attraction of flies to eye secretions seems to be due to an olfactory response rather than to a humidity response as the flies always avoided moisture.

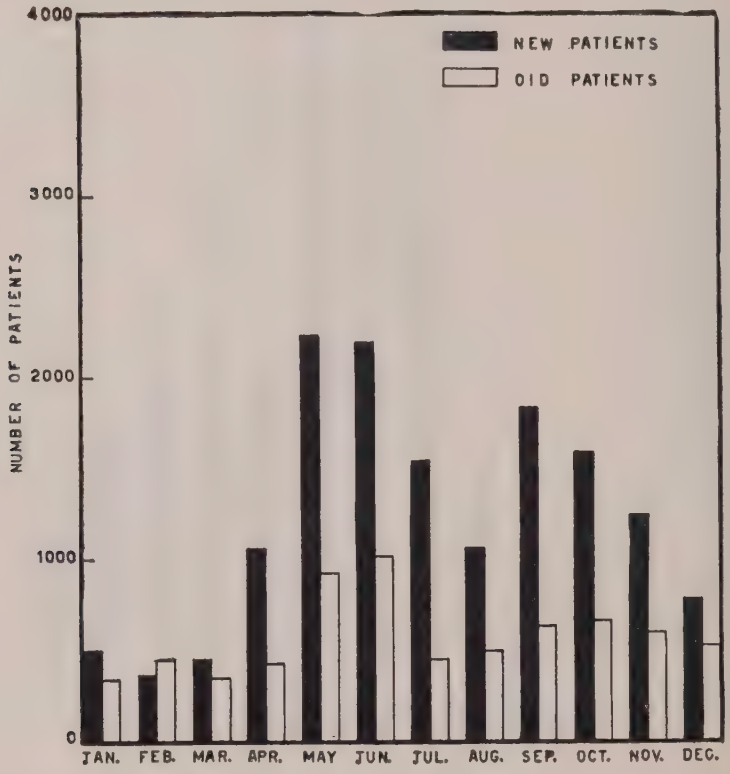

FIG. 3: The incidence of ophthalmiasis during the year 1954, constructed from data available at the University Children Hospital, Cairo.

This was demonstrated in a series of experiments in which the flies were offered 20-40, 40-60, 60-80, 80-100% as alternatives. In almost all cases the flies avoided the moister side and aggregated on the drier side (Table V). Using either conditioned or unconditioned flies the same general behaviour was obtained, flies preferred strikingly the drier side. Similar reactions to air humidity about *M. domestica* were reported by DAKSHINAMURTY (1948).

TABLE III

Out patient treatment, Children's Department (Hospital), classified monthly during the year 1954.

Date	New patients			Old patients			General total
	male	female	total	male	female	total	
January	273	240	513	196	186	382	895
February....	208	179	387	236	206	442	829
March	235	227	462	195	184	379	841
April	563	510	1073	211	200	411	1484
May.....	1166	1055	2221	486	417	903	3124
June.....	1155	1054	2209	524	491	1015	3224
July	730	821	1551	232	209	441	1992
August ...	548	519	1067	264	235	499	1566
September	951	868	1819	358	303	661	2480
October	818	777	1595	375	310	685	2280
November	628	604	1232	338	279	617	1849
December	412	378	790	279	251	530	1320

TABLE IV

The incidence of eye diseases and the population density of Musca sorbens *in five residential districts.*

Locality		Total patients	Fly index
High residential	Kasr El Nil	4	13
	Manial	6	16
Low residential	Old Cairo	41	28
	Giza	30	37
	Gayyara (Saida)	117	42

TABLE V

The percentage flies settling on the drier side in an alternative chamber (average of 10 experiments).

Sex	Percentage of flies on the drier side			
	20-40% R.H.	40-60% R.H.	60-80% R.H.	80-100% R.H.
Male	69	67	63	60
Female	67	63	62	59

The results obtained in the course of the present work point out that *M. sorbens* more than the common house fly, *M. domestica vicina*, may be incriminated as the main vector of eye diseases in Egypt. This is supported by : (1) in the

greater part of the year, the majority of flies caught on diseased eyes belong to this species; (2) peaks of both fly seasonal abundance and incidence of eye diseases nearly coincide; (3) eye diseases are most prevalent in districts with no sewage disposal system where defecation occurs in the open and where *M. sorbens* as a consequence breeds extensively; (4) the fly's attraction to diseased eyes is an olfactory response rather than a humidity reaction.

The results obtained by De Coursey et Al. (1956) from their bacteriological studies on this fly, on the other hand, seem also to lend support to the above conclusion. These authors have studied experimentally the bacterial types found in *M. domestica vicina* and *M. sorbens* and stated that the greater number of ophthalmias caused by fly habitation on the faces and eyes of children in Egypt is an infection caused by *Streptococci*, *Staphylococci* and possibly in some instances by enteric bacteria. According to these authors these forms of bacteria occur more abundantly on *sorbens* than on *vicina* in April, May, June and August. This occurrence generally coincides with the peaks of fly seasonal abundance according to our results.

SUMMARY

The relation of *M. sorbens* to eye diseases in Egypt has been studied both in the field and in the laboratory. The results obtained from fly catches on diseased eyes, the seasonal prevalence of both fly and ophthalmiasis, and the incidence of eye diseases in low and high residential districts all seem to emphasise the role played by this species in the transmission of ophthalmia in Egypt. Bacteriological evidence to this effect has been brought forward by De Coursey and others. It has been further demonstrated by the present authors that the attraction of this fly to diseased eyes is due to an olfactory response rather than to a humidity reaction.

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THE EFFECTIVENESS OF SOME INSECTICIDES ON *TROGOXYLON IMPRESSUS* COM.

[*Coleoptera* : *Lyctidae*]

(with 1 Graph and 2 Tables)

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INTRODUCTION

Although for many years the Lyctid powder-post beetles have been recognized as serious pests by dealers and utilizers of wood products in Egypt, yet their control in floors and furnitures was very little studied in our country. The purpose of this study, which has been carried out at the Entomological Section of the Ministry of Agriculture, is to obtain information concerning the effectiveness of insecticides in preventing attack by these insects. This paper deals with the initial and the remedial effects of the problem.

THE INITIAL EFFECT

Technique

Series of tests were established in May 1956 and conducted upon *Trogoxylon impressus* Comolli. Various chemicals were applied as 3 minutes dips to boards of oak floor wood, 4 inches log, 1 inch thick and 1.5 inches wide. The dips were: toxaphene, pentachlorophenol, lindane, DDT, dieldrin, creosote and paradichlorobenzene; the solvent was kerosene.

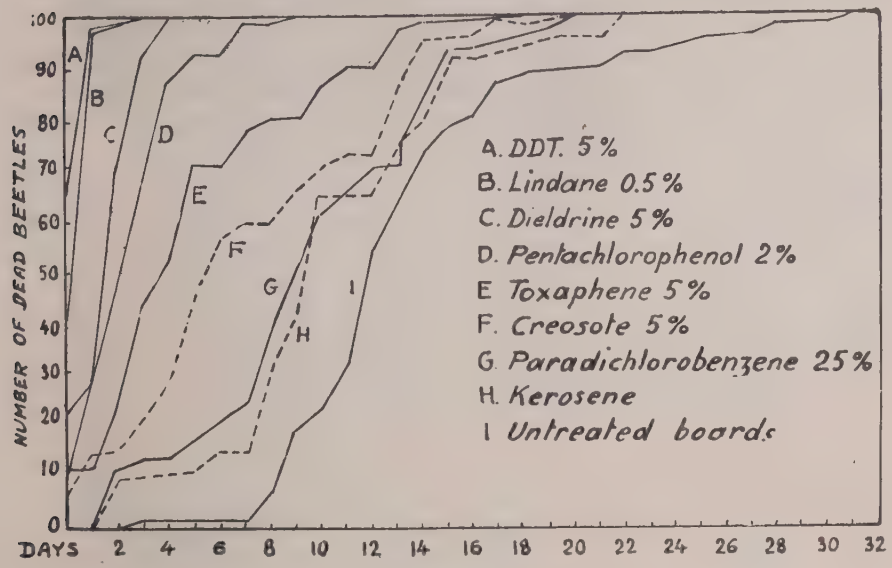
Five samples were treated with each chemical formulation. As control, a similar number of boards were treated with kerosene and equal number were left untreated. The treated samples were placed in the open air until their surfaces were dry, then each board was placed in a jar covered with muslin. Seven days after treatment, 20 adults of *Trogoxylon impressus* were liberated on each test sample.

TABLE I

Chemicals	Number of dead beetles after hours :																																
	1	2	6	24	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
DDT. 5%	0	6	66	98	99	100																												
Lindane (gamma isomer 0.5%)	4	10	39	97	99	100																												
Dieldrine 5%...	2	6	9	29	70	92	100																											
Pentachlorophenol 2%	3	9	22	29	46	66	87	93	93	99	99	100																						
Toxaphene 5%	0	10	11	12	22	44	52	71	71	78	80	80	86	90	90	97	99	99	99	991	00													
Creosote 5%	2	2	6	14	16	20	28	45	56	60	60	66	70	73	73	85	96	96	96	99	99	99	100											
Paradichlorobenzene 25%.....	0	0	0	0	12	14	14	18	20	25	40	50	61	65	70	71	84	94	94	95	96	98	100											
Kerosene....	0	0	0	0	10	10	11	11	15	15	30	42	65	65	66	75	80	92	92	93	94	96	96	96	100									
Untreated boards	0	0	0	0	0	1	1	1	1	1	5	19	22	31	55	65	73	78	80	87	89	90	90	90	93	93	95	96	96	97	99	99	99	100

Table I shows the formulations tested and the number of dead beetles found after liberation at intervals of 1, 2, 6, 24, and then every 24 hours. Graph I represents the daily counts.

GRAPH I



Results

1. — The action of DDT. and lindane was very rapid; 98% of the beetles were killed within 24 hours.

2. — Dieldrin killed more than 90% of the beetles after three days.

3. — There was no significant difference between creosote, paradichlorobenze ne, and kerosene.

4. — Treatment with pentachlorophenol was more effective than toxaphene.

Summary

Both solutions of 5% DDT. in kerosene and the solution of lindane (0.5% gamma isomer) in kerosene had high and rapid initial toxicity, which allow no chances of oviposition.

THE REMEDIAL EFFECT

Technique

Series of tests were established in January 1956 to determine the effectiveness of various chemical formulations in controlling Lyctid powder-post beetles in oak floor wood boards which were infested with *Trogoxylon impressus* larvae.

The boards were previously infested by placing them in jars and exposing them to beetles during April, and again in September, 1955. They were laid on the shelves in the laboratory for a period of two weeks during January, 1956, so that observations could be made of the degrees of infestation, as indicated by the quantity of powder falling from them. An effort was made to have samples of equal degrees of infestation.

The tested chemicals were toxaphene, pentachlorophenol, lindane, DDT., dieldrin, creosote and paradichlorobenzene; and the solvent used was kerosene. Six boards were treated with each chemical formulation by dipping for 3 minutes. As control, a similar number of boards were treated with kerosene and an equal number were left untreated. The treated samples were placed in the open air until their surfaces were dry. Then each board was placed in a jar covered with muslin.

Inspections were made during the period of February, March and April, 1956, to determine the number of adult *Trogoxylon impressus* that emerged from each board. Final results were obtained during May. One-half of the boards were also split and examined for living and dead larvae.

Table II shows the formulations tested, the number of adults that emerged, and the number of larvae found in the split boards.

TABLE II

Chemicals	Number of adults emerged between February and April	Number of larvae in split samples in May	
		Dead	Living
DDT. 5%	0	19	0
Lindane (gamma isomer 0.5%) .	0	23	0
Dieldrin 0.5%	0	17	0
Pentachlorophenol 2%	0	26	0
Toxaphene 5%	0	21	0
Creosote 5%	0	18	0
Paradichlorobenzene 25%	0	15	0
Kerosene	0	19	0
Untreated boards	68	2	6

Results

1. — All the chemical formulations and the kerosene alone were highly effective in controlling infestation of *Trogoxylon* larvae.

2. — The infested samples used in these remedial tests had some emergence holes in them, but were usable.

3. — The emergence holes increased the degree of penetration of the chemical formulations.

4. — The use of dyes as tracers in the dip treatments showed that formulations had penetrated throughout almost all of the larval tunnels.

Summary

1. — Since kerosene alone gave complete control and killed all the larvae present, the addition of chemicals is useless from the standpoint of remedy. On the other hand, the use of kerosene alone could not be expected to prevent reinfestation and the addition of an effective chemical, having a long residual effect, would prevent further attack for sometime.

2. — Creosote, a cheap and effective insecticide has also given satisfactory results.

THE MORPHOLOGY AND ANATOMY OF THE MATURE LARVA OF *PRODENIA LITURA* F.

[*Lepidoptera*: *Agrotidae-Xenobiinae*]

(with 7 Text-Figures)

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CONTENTS

I. Introduction. — II. Material and technique. — III. External morphology of the larva. — IV. Anatomy of the larva (glands, alimentary canal, respiratory system, nervous system, muscular system, circulatory system and associated structures, oenocytes, reproductive system). — V. Acknowledgments. — VI. References,

I. INTRODUCTION

Prodenia litura F. is a major pest of cotton plants and many other crops and vegetables.

Although its larva causes great damage in different parts of the world, yet no work has been done on its anatomy. GARDINER (1941, 1946) gave few descriptive notes on it, and WOKE (1941) worked on the structure and development of the larval alimentary canal of a closely related species, *Prodenia eridania*, which occurs in America.

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II. MATERIAL AND TECHNIQUE

Specimens of the larva were obtained either by field collecting or by rearing. Preservation was made in 70% alcohol.

Pe manent preparations of the integument were made for studying the chaetotaxy. Morphological and anatomical studies were made only on the sixth instar larva. It was found useful to stain the tissues with a weak solution of Delafield's haematoxylin for differentiating the fine structures. especially the sympathetic nervous system.

The terminology and abreviations employed in this work are, in most cases, those of SNODGRASS (1935).

III. EXTERNAL MORPHOLOGY OF THE MATURE LARVA

Body stout and sub-circular in cross-section, measuring about 30-50 mm. long. and provided with setae as shown in Figure 1G. Each of the five abdominal pairs of prolegs (Fig. 3 E, F, G, J, K) is provided with crochets amounting to 22, 23. 25, 25 and 28 from the first to the anal pair, respectively. The last pair of prolegs (Fig. 3J, K) differs slightly from the others. especially in the position of the sclerotic plates and the number of setae which it bears. There is a prominent swelling (Scx) of the body wall above each proleg and thoracic leg. Corresponding swellings are present on the legless segments of the abdomen. SNODGRASS (1935) mentions that these swellings appear to represent the lateral parts of the sub-coxae on both the thorax and the abdomen.

HINTON'S nomenclature (1948) for the cranial areas and sutures is adopted in this paper. Head-capsule about 2.5 mm. in width, with shape, sutures and setae as shown in Figure 1 A, B, D, E. Each parietal carries, near the base of the antenna, six ocelli. five of them being arranged in a semi-circle, and the sixth located in their diameter near the antenna. The head bears two reduced antennae, each consisting of three segments. Antenna with setae as shown in Figure 1 C,F. As in other caterpillars, a number of strong ridges has developed internally in the head-capsule of *Prodenia litura* as shown in Figure 1B.

The tentorium (Fig. 1B) consists of two anterior and two posterior arms. The anterior arms (AT) are slender longitudinal bars, arising from the arms of the inverted Y-shaped internal ridge (AIR) near its lower ends. They extend horizontally through the head, and are united posteriorly with the posterior arms (PT). The posterior arms arise from the inner ends of the ventral postoccipital apodemes (vap) at the posterior angles of the hypostomal plates. These posterior arms are united together forming the posterior bridge (Tot) which assumes the appearance of a delicate white thread. In correlation with the origin of these arms from strong ridges, the tentorial pits are wanting.

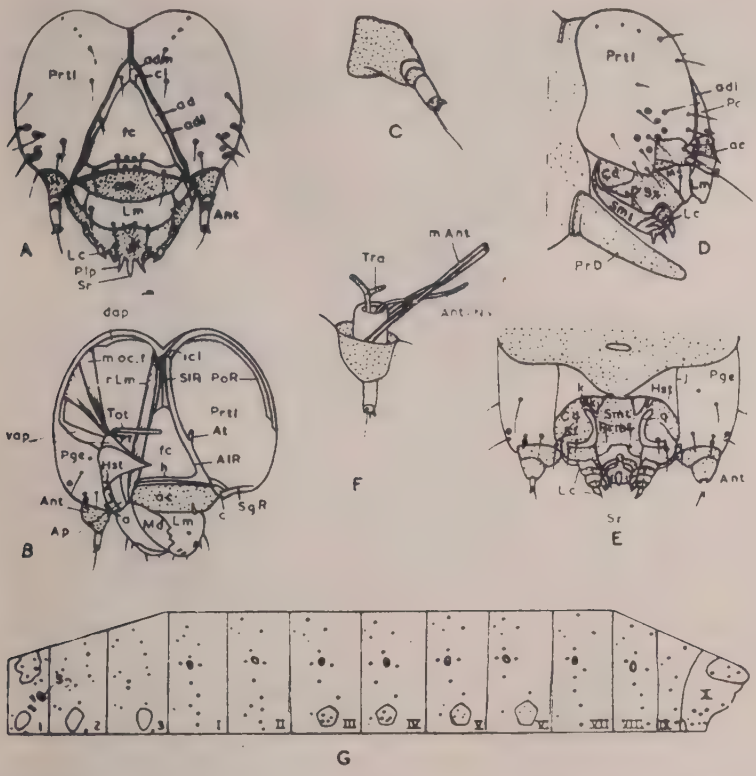

FIG. 1: A, dorsal view of head-capsule. — B, ventral view of head-capsule with the right postgena, hypostoma, antenna, mandible and labral muscle cut away. — C, lateral view of right antenna. — D, lateral view of head capsule. — E, ventral view of head-capsule. — F, Posterior view of left antenna. — G, situations of setae of left side of body.

(1-3, thoracic segments; I-X, abdominal segments; a, posterior articulation of mandible; as, anteclypeus; ad, adfrontal area; adl, lateral adfrontal suture; adm, median adfrontal suture; AIR, arm of internal ridge; Ant, antenna; Ant. Nv, antennal nerve; Ap, base of adductor apodeme of mandible; At, anterior arm of tentorium; c, anterior articulation of mandible; Cd, cardo; dap, dorsal apodemal plate of postoccipital ridge; fc, frontoclypeal area; h, internal thickening of postclypeus; Hst, hypostome; icl, internal horizontal cleavage line; j, hypostomal suture; k and k_1, accessory plates of cardo; Lc, terminal lobe of maxilla; m. Ant, muscles of antenna; Md, mandible; m.o.c.f., muscles of occipital foramen; Pge, postgena; Plp, labial palp; PoR, postocciptal ridge; PrD, duct of repugnatorial gland; Prmt, prementum; Prtl, parietal; PT, posterior arm of tentorium; q, external line of stipitial ridge; r. lm, retractor of labrum; SgR, hypostomal ridge running along hypostomal suture; SIR, stem of internal ridge; Smt, submentum; Sr, spinneret; St, stripes; Tot, transverse bar of tentorium; Tra, trachea; vap, ventral apodemal plate of postoccipital ridge).

Mandibles (Fig. 2A) with six teeth. Each mandible bears two long setae on its lateral side. Labrum (Fig. 2C) with 12 setae. Epipharynx with six conical setae, a pair of punctures and numerous microtrichia which are considered by

DETHIER (1937) to be gustatory organs. There are two lateral chitinized tormae (Tor) attached to the proximal margin of the epipharynx. The maxillae, labium and epipharynx are united together to form a composite structure bearing the spinneret at its tip (Fig. 2D,E). Each maxilla is composed of three parts, a cardinal

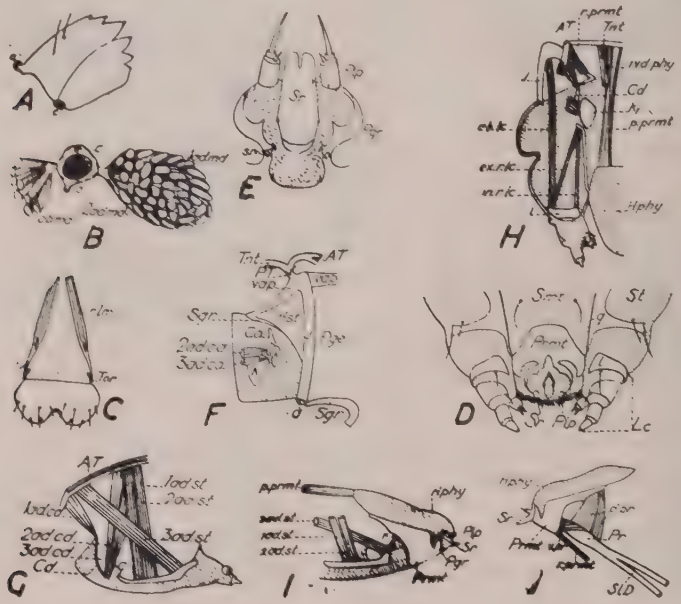

FIG. 2: A, antero-lateral view of mandible. — B, upper view of left mandible with bases of its muscles. — C, dorsal view of labrum. — D, ventral view of distal end of maxillae and labium. — E, ventral view of distal end of labium. — F, internal view of left postgenal, hypostomal and cardinal regions. — G, lateral view of right maxilla showing muscle attachments. — H, internal view of right maxilla and hypostomal regions. — I, lateral view of distal part of labium. — J, lateral view of distal part of labium, hypopharunx and silk press.

(ab.md, abductor muscles of mandible; ab.1c, abductor muscle of terminal free lobe of maxilla; 1 ad. cd, 3 ad. cd; adductor muscles of cardo; 1 ad.md, 2ad.md, adductor muscles of mandible; 1 ad. st, 3 ad. St, adductor muscles of stipes; d.pr, dorsal muscles of silk press; ex.r.1c, external retractor muscle of terminal free lobe of maxilla; Hphy, hypopharynx; in.r.1c, internal retractor muscle of terminal free lobe of maxilla; 1, basal sclerite of terminal free lobe of maxilla; Pgr, palpiger; Pr, silk press; p, prmt, protractor muscle of spinneret bearing lobe; r, articular nodule between stipitial arm and prementum; r. prmt, retractor muscle of spinneret bearing lobe; Sgr, sugenal ridge; Sld, duct of silk gland; sr, sensorium; Tnt, tentorial bridge; Tor, tormae; 1vd. phy, first ventral dilator muscle of pharynx; v.pr, ventral muscle of silk press).

Other lettering as in Figure 1.

area, a stipital area and a free terminal lobe. Both areas of the cardo and stipes are united with the basal part of the labium. They are membranous with small chitinized areas. Maxillae and labium with palpi, sclerites and setae as shown in Figure

2D-J. The silk-press (Fig. 2J), in which the ducts of the silk glands open, is located between the prementum and the base of the hypopharynx. This silk-press is oval in shape with an invaginated dorsal wall. The hypopharynx (Fig. 21 J, Hphy) is provided with numerous microtrichia or the gustatory organs of DETHIER (1937).

IV. ANATOMY OF THE LARVA

The glands

The mandibular glands (Fig. 4 A) are a pair of cylindrical, twisted processes extending from behind the first pair of spiracles and ending near the insertion of the mandibular adductor muscles. Each gland is about 3.4 mm. long and 0.1 mm. in diameter. The labial gland (Fig. 4 B) is a long tube, about 15 mm. long, and tapering gradually towards its posterior end. Its large anterior end measures about 0.5 mm. in diameter whereas its posterior end is about 0.15 mm. It extends from the fourth abdominal segment to about the posterior margin of the second abdominal segment where it turns backwards to the third abdominal segment and then turns forwards again and runs until it reaches the metathoracic segment.

A long thin duct (SID), about 0.1 mm. in diameter, proceeds from the anterior end of each gland through the thorax until it reaches the sub-oesophageal ganglion, beneath which it runs and unites with the other duct of the opposite side, to form a short common opening in the silk-press (Pr.). From the latter, a fine duct extends anteriorly to enter the spinneret.

Associated with each silk gland is an accessory gland, the FILIPPI'S gland (Fig. 1) Which is ribbon-like, located in the prothorax and opening into the duct of the silk gland of its side.

In the ventral region of the neck, there is a distinct slit (Fig. 1E) which is the aperture of the repugnatorial gland (Fig. 4C). This gland consists of a pyriform sac (sac) and a duct (PrD). The duct is divided into two parts, the anterior one being rectangular in shape while the posterior is conical. The gland lies in the mid-ventral part of the prothorax under the ventral nerve-cord. The length of the pyriform sac and its duct is about 2 mm., while the widest end of the sac is about 0.5 mm. in diameter.

The muscles of the gland are arranged in pairs along its anterior lateral margins, as shown in Figure 4C.

When the gland becomes into action, the duct is thrust out through the slit with the glandular sac reversed in it (Fig. 1D). When it is at rest, it returns to its usual shape and position in the prothorax by means of its muscles.

The alimentary canal

The bucco-pharynx (Fig. 4D, Buc) is about 0.23 mm. long. It has two transverse muscular bands (a,b) on its dorsal side and a broad muscle band (d) on its

ventral side. These muscles are inserted laterally on two oblique ridges (r), one on each side of the anterior part of the fore-gut. These ridges are developed from the intima of the fore-gut. There are four pairs of dorsal dilator muscles of the buccal cavity (1dd. buc-4dd.buc).

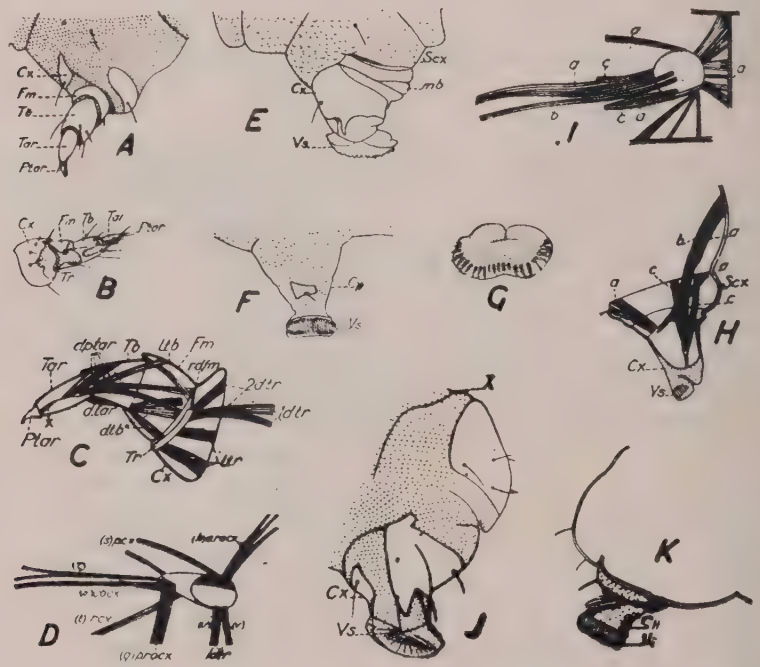

FIG. 3: A, lateral view of left metathoracic leg. — B, internal view of same. — C, muscles of left metathoracic leg. — D, dorsal view of interior part of coxa. — E, lateral view of first left proleg. — F, internal view of same. — G, ventral view of planta. — H, muscles of the first proleg. — I, dorsal view of interior upper part of left proleg (seen after dissection). — J, lateral view of left anal proleg. — K, internal view of same.

(a, muscles inserted on base of proleg; ab.c, abductor muscles of coxa; a.ro.cx, anterior retractor muscles of coxa; b, plantar muscles arising on lateral body wall; C, plantar muscles arising on base of proleg; Cx, cylindrical part; d. ptar, depressor muscles of pretarsus; d. tar, depressor muscle of tarsus; d.tb, depressor muscle of tibia; 1d.tr and d.tr., first and second group of depressor muscles of trochanter; Fm, femur, l.tb, levator muscle of tibia; l.tr, levator muscle of trochanter; m.b., ring of flexible integument; p.cx, protractor muscles of coxa; p.ro.cx, posterior rotator muscles of coxa; P. tar, pretarsus; r.cx, rotator muscle of coxa; rd.fm., reductor muscle of femur; S. cx, swelling represents lateral part of subcoxa; Tar, tarsus; Tb, tibia; Tr, trochanter; Vs, planta; X, anterior margin of last abdominal segment).

The pharynx is about 0.38 mm. long. Its anterior dorsal part is covered by a broad transverse muscle (c) attached laterally to the oblique ridges (r), while the posterior dorsal wall is covered with longitudinal muscles (g). There are also two

longitudinal slender muscles of a deeper set, arising anteriorly on the buccal region beneath the first transverse muscle (a). These muscles extend posteriorly to the posterior end of the pharynx. On each lateral side of the pharynx, there are two longitudinal muscles (f,e) attached to the oblique ridge and extending posteriorly to the oesophagus. There are also some longitudinal muscles covering the ventral wall of the pharynx. The pharynx is provided with seven pairs of dilator muscles, four dorsal pairs (1dd. phy-4dd. phy) and three ventral pairs (1vd.phy-3vd.phy).

The oesophagus (Fig. 3D,Oe) is about 2 mm. long. It is surrounded by a series of strong circular muscles. It has also three pairs of fan-like dorsal dilator muscles (dd.oe) and three other similar pairs of ventral dilator muscles (vd.oe).

The walls of the pharynx and oesophagus are disposed in six longitudinal folds, projecting into the lumen and extending from the buccal cavity to the posterior end of the oesophagus. These folds disappear near the posterior end of the oesophagus with the sudden widening of the fore-gut into the crop.

At the posterior ends of the ventro-lateral folds of the oesophagus, there are two large invaginated structures bearing numerous small chitinous processes. Each structure is rectangular in shape and measures about 800 μ long, 166 μ wide and 200 μ high. Woke (1941) stated that these structures assist the circular muscles, which lie at the end of the oesophagus, in forming a barrier against the return of food materials from the crop.

The crop (Fig. 4D, E; Cr) is about 3.6 mm. long. It is surrounded by longitudinal muscles (m) which branch and unite together forming a network of muscles. About the middle of the crop, there are three rings of circular muscles (l).

The proventriculus (Fig. 4E, Pvent), measuring about 2.4 mm. long, is surrounded internally by a series of circular muscles connected together by finer branches and externally by a layer of fine, widely spaced longitudinal muscles.

Between the fore-gut and the mid-gut, there is a distinct invaginated portion of the posterior end of the fore-gut, the cardiac valve. The mid-gut (Fig. 4F, Ment) being about 26 mm. long, has the form of a large tube of almost uniform diameter throughout its length. It extends from its junction with the fore-gut in the metathorax throughout the first six abdominal segments. It is attached to the body-wall by slender muscles arising on the posterior margins of the pro- and mesothorax. At the anterior end of the mid-gut, there are four groups of small rounded gastric caeca. The musculature of the mid-gut consists of an outer longitudinal (n,1b) and an inner circular (c) muscle layers.

The total length of the hind-gut (Fig. 4F) is approximately 8 mm. The anterior and posterior intestines are almost equal in length, each about 3 mm. The pylorus is shorter, measuring about 2 mm.

The wide anterior part of the pylorus (Py) is calyx-like, while its posterior end represents a narrow stalk surrounded by strong external sphincter muscles (sptr). The anterior margin of the pylorus is marked, externally, from the mid-gut by a strong band of circular muscles (g) and internally by a corresponding

fold. The musculature of the pylorus consists of two layers of muscle fibers, an external layer of widely separated and branching longitudinal muscles (1mcl) which pass posteriorly beneath the pyloric sphincter (sptr) and an inner layer composed of close series of circular muscles.

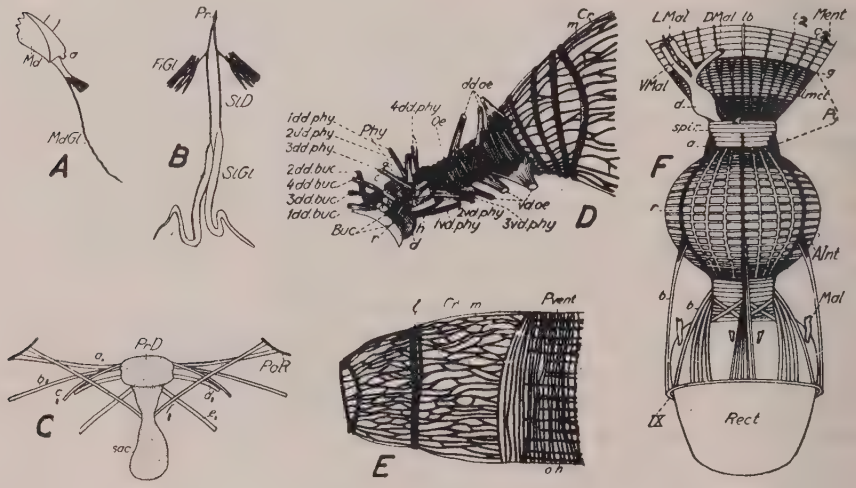

FIG. 4 : A, ventral view of right mandibular gland. — B, dorsal view of silk glands. — C, dorsal view of repugnatorial gland. — D, anterior part of fore-gut. — E, posterior part of fore-gut. — F, hind-gut with all parts well distented to show their minuted structure.

(a_1,b_1,c_1,d_1,$e1$,f_1, muscles of repugantorial gland; a, b, d, muscle bands surrounding buccal region; c, e, f, g, h, muscle bands surrounding pharynx; C_2, circular muscles of mid-gut; AInt, anterior intestine; Buc, buccal region; 1 dd.buc.4dd.buc, dorsal dilator muscles of buccal cavity; 1dd.phy.4dd.phy, dorsal dilator muscles of pharynx; dd. oe, dorsal dilator muscles of oesophagus; DMal, dorsal Malpighian tubule; F. Gl, Filippi's gland; 1, circular muscles of crop; 1_1, longitudianl muscles of mid-gut; 1b, longitudinal muscle band of mid-gut; LMal, lateral Malpighian tubule; 1mcl, external longitudinal muscles of pylorus; m, longitudinal muscles of crop; Mal, Malpighian tubule; Md, mandible; Ment, mid-gut; MdGl, mandibular gland; N, circular muscles of proventriculus; o, external longitudinal muscles of proventriculus; Oe, oesophagus; Phy, pharynx; Pr, silk press; PrD, duct of repugnatorial gland; Pvent, proventriculus; Py, pylorus; r, oblique ridge; r_1, ridge of anterior intestine; Rect, rectum; sac, pyriform sac of repugnatorial gland; SlD, duct of silk gland; SlGl, silk gland; sptr, pyloric sphincter; vd.oe, ventral dilator muscles of oesophagus; 1vd. Phy. 3vd. phy, ventral dilator muscles of pharynx; VMal, ventral Malpighian tubule).

The pyloric valve is situated in the narrow posterior region of the pylorus of which the inner walls are thrown into four large folds and form opposing lobes that block the narrow entrance of the anterior intestine.

The walls of the anterior intestine or colon (AInt) are characterized by the presence of six longitudinal ridges (r) formed by special development of the intima for the insertion of the external circular muscles which occur between these ridges.

There are six groups of external, short muscle fibers (a) arising of the longitudinal ridges (r) of the anterior intestine and are inserted upon the narrow posterior part of the pylorus between the strong muscle bands forming the pyloric sphincter. There are also six large groups of external slender muscles (b) arising on the body-wall on the line between the eighth and ninth abdominal segments (IX). These muscles are inserted on the longitudinal ridges of the anterior intestine. Some of them are inserted about the middle of the anterior intestine, others on its posterior end, i.e. on the wall of the rectal sphincter.

The rectal valve appears as a constricted region between the anterior and posterior intestines. It is surrounded externally by broad muscle bands which lie close together. The inner walls are thrown into large folds that block the narrow entrance of the rectum.

The posterior intestine or rectum (Rect) is a sac-like chamber and opens posteriorly in the anus. It has six groups of crossing muscles, each group comprises three pairs of crossing muscles lying over each other. Underneath these crossing muscles, there are circular muscle bands running around the anterior part of the rectum. The anterior part of the rectum is surrounded by six groups of slender muscles (b) that extend between the longitudinal ridge (r) of the anterior intestine and the anterior margin of the ninth abdominal segment. Besides, there are many longitudinal and oblique muscles that encircle the posterior part of the rectum.

There are three Malpighian tubules (Fig. 4F) running along each side of the mid-gut, one lying dorsally (DMal), the other laterally (LMal) and the third ventrally (VMal). The dorsal and lateral tubes are fused together posteriorly to form a short tube. This tube joins the ventral one to form a short common duct which becomes dilated (d) and opens into the hind-gut. The terminal ends of the three Malpighian tubes enter the rectal walls at their anterior parts.

The respiratory system

On each side of the body, there is a longitudinal trachea (Fig. 5, LTra) extending posteriorly from the first spiracle to the last with the other spiracles opening into it. Although the metathoracic spiracles are rudimentary, the site of each is connected with the longitudinal trachea by a stigmatic cord. The longitudinal trachea of both sides are connected by transverse ventral and dorsal commissures (VCom and DCom). In the metathorax, a large branch from the main trachea passes beneath the sterno-tergal muscles. In the first abdominal segment, two branches from the spiracle pass between the sterno-tergal muscles and the body wall.

There are three dorsal transverse commissures (Fig. 5A,B) located above the alimentary canal in the head, in the prothorax and in the eighth abdominal segment. The first two dorsal transverse commissures are formed from branches of the mesothoracic spiracles. A main trachea (1) arises from the mesothoracic spiracle and runs anteriorly for a short distance, then branches into two tracheae; the inner one branches into two unequal tracheae. The larger trachea (f) runs upward

to meet a corresponding branch from the opposite side in the posterior dorsal part of the head to form the anterior dorsal transverse commissure (Dcom). From the apex of this commissure, two pairs of branches diverge anteriorly into the head. The posterior small branch (q) runs posteriorly to meet a corrresponding branch from the opposite side in the prothorax to form the second dorsal transverse commissure. Each branch then proceeds backwards and outwards until it meets another

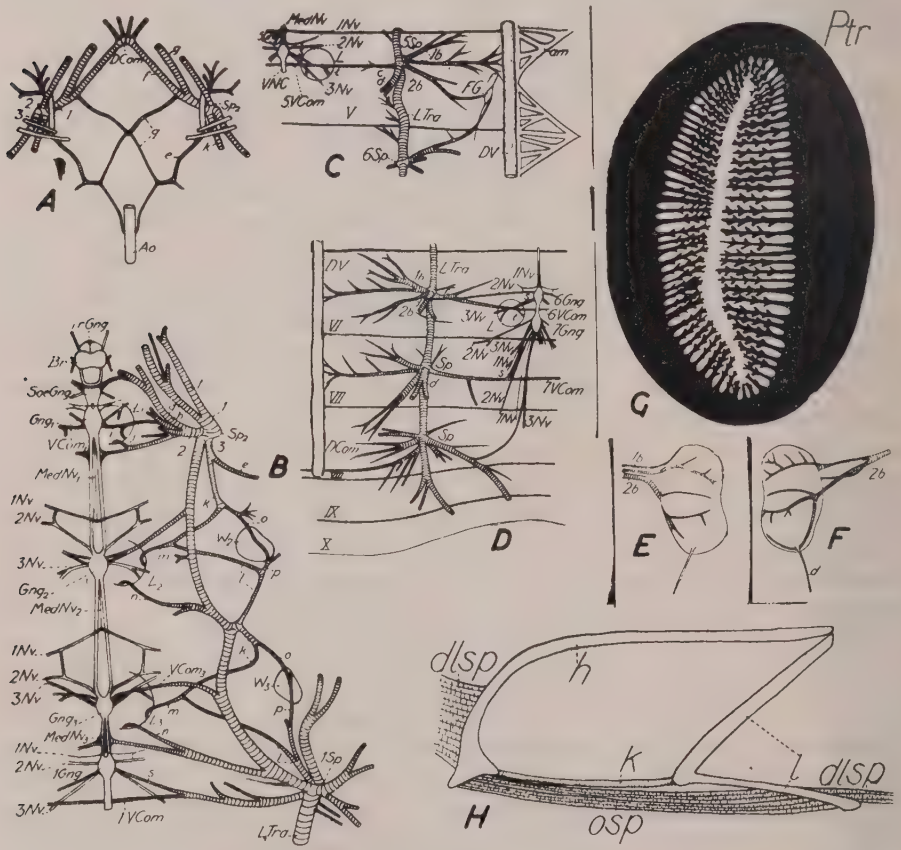

FIG. 5 : A, dorsal tracheal commissures locating in head and prothorax (ventral view). — B, the nervous system and tracheae of the right part of the head and thorax. — C, right side of fifth abdominal segment with the corresponding anterior part of sixth abdominal segment. — D, left side of sixth to last abdominal segments. — E, tracheation of right male gonad (dorsal view). — F, left male gonad (dorsal view). — G, external view of fourth abdominal spiracle. — H, internal view of closing apparatus of fourth abdominal spiracle.

(am, alary muscles; Ao, aorta; b, dorsal tracheae; Br, brain; C, ventral tracheae; CoeCon, circum-oesophageal connectives; d, visceral tracheae; D Com, dorsal tracheal commissures; Dlsp dilator muscles of spiracular closing apparatus; DV, dorsal vessel; FG, female gonad; Gng1 — Gng 3, thoracic ganglia; 5 Gng - 7 Gng, fifth to last abdominal ganglia; h, closing bow, K, closing band; L, proleg; 1, closing lever; LTra, longitudinal lateral tracheae; MedNv 1 - Med Nv. 3,

median nerves; 1 Nv - 3 Nv, lateral nerves; osp, closing muscle; s, tracheae supplying the nerve ganglia; SoeGng, subœsophageal ganglion; 1 Sp, 5 Sp - 8 Sp and Sp 2, first abdominals piracle, fifth-eighth abdominal spiracles and mesothoracic spiracle; t, tracheae supplying prolegs; VCom-1 VCom 3, ventral tracheal commissures of thoracic segments; 5VCom- 7 VCom, ventral tracheal commissures of corresponding abdominal segments; W2 and W3, wing-buds of meso- and metathorax. Roman numbers refer to abdominal segments).

branch (e) from the mesothoracic spiracle. Thus, the second dorsal commissure appears x-shaped. The last dorsal commissure occurs in the posterior region of the eighth abdominal segment (Fig. 5D) and it is formed by the union of two branches coming from the last spiracles.

In each of the thoracic and first seven abdominal segments, there is a well developed ventral commissure (Fig. 5B,C and D) crossing the anterior part of the sternal region beneath the ventral nerve-cord. There is another ventral commissure located posteriorly in the head. It is formed from the branches of the mesothoracic spiracles.

From each of the mesothoracic spiracles (Fig. 5A and A) are given off three main trachea. The anterior trachea (1) forks in front of the spiracle, its inner branch divides again into two branches (f,q) which meet the corresponding branches of the opposite side to form the first two dorsal commissures. The outer branch (g) breaks up into large branches which supply the side of the head; it also gives off a minute branch to the brain. The second main trachea (2) divides into three branches, the anterior branch (h) of which extends into the head and supplies the maxillae and the labium. A small branch from this trachea extends mesally to meet a corresponding branch over the sub-oesophageal ganglion. From this transverse commissure two small branches supply the sub-oesophageal ganglion. The middle branch divides into two, one of them unites with its corresponding branch of the opposite side to form the first ventral commissure (VCom 1) which supplies the ganglion. the gland and the legs of the prothorax. The other branch innervates the thoracic muscles. The third branch of the second main trachea divides into two; one of them supplies the fore-gut, and the other supplies the prothoracic leg and the body muscles. The third main trachea (3) arising posteriorly from the mesothoracic spiracle soon forks to supply the mesothoracic leg and wing rudiment and to unite with the second dorsal commissure.

The tracheae which are given off from the longitudinal tracheae in the first seven abdominal spiracles are similar to each other (Fig. 5B,C and D). Adjacent to each spiracle, there are two dorsal tracheae (1b, 2b), a ventral trachea (c), and a median visceral one (d) which divides into two branches to supply the dorsal and ventral parts of the alimentary canal. The ventral trachea (c) meets a corresponding one from the opposite side to form the ventral commissure of its segment. The anterior dorsal trachea (1b) soon divides into two branches. In the first abdominal segment, there is an additional trachea supplying the metathoracic leg and wing rudiment. From the last spiracle of the abdomen, arise three dorsal tracheae in

addition to two ventral tracheae. Posteriorly, it gives off two large tracheae which supply the succeeding segments.

There are two pairs of wing rudiments (Fig. 5B); one in the mesothorax (W_2) and the other in the metathorax (W_3). Each wing rudiment is penetrated from the opposite ends by two tracheae (o,p) given off from the arms of the lateral Y-shaped leg trachea (k,l) of the same segment.

The alimentary canal is well tracheated by the large visceral tracheae (Fig. 5C and D). The supplying trachea arising from the first abdominal spiracle differs in origin from other tracheae. It does not arise directly from the longitudinal trachea, but from the spiracular one. Each visceral trachea forks into two branches; one running dorsally and the other ventrally. Then each one branches again to supply the alimentary canal. The posterior part of the alimentary canal lying in the ninth and tenth abdominal segments, is well supplied by branches from the spiracles of the eighth abdominal segment. In the thorax, there is a small trachea arising from the mesothoracic spiracle that supplies the ventral surface of the oesophagus.

Tracheae supplying the brain, the sub-oesophageal and prothoracic ganglia, have been already mentioned. Each of the mesothoracic ganglia receives wo branches (Fig. 5B, C, D;s) from the ventral commissure of its segment. Each of the first six abdominal ganglia, receives also two branches (s,s) from the ventral commissure of its segment. The last ganglion receives four tracheae; two from the ventral commissure of the seventh abdominal segment and the other two arise from branches of the tracheae derived from the last pair of spiracles. The connectives between the thoracic ganglia are supplied by branches arising from the tracheae (j,n) that supply mesally the thoracic legs.

Each thoracic leg has two tracheae, one lateral, the other median (Fig. 5B; L_1-L_3). In the prothorax, the lateral trachea of the leg (i) is derived from the ventral commissure. The median (j) comes directly from the branches of the mesothoracic spiracle. In the mesothorax and metathorax, the lateral trachea of the leg (m) is a branch formed, in the case of mesothoracic legs (L_2), by the union of two tracheae (k,l) from the mesothoracic and metathoracic spiracles and in the case of metathoracic legs (L_3), from the metathoracic and the first abdominal spiracles. The median trachea (n) of the leg in these segments, springs from the longitudinal trachea in the neighbourhood of the following spiracle.

Each proleg (Fig. 5C,D;L), except the last pair, is supplied with a branch (t) from the ventral commissure of its segment. The last anal prolegs are supplied with tracheae arising from the last pair of spiracles.

The heart (Fig. 5C, D; DV) is tracheated by terminal branches of the dorsal tracheae (b) of the abdominal spiracles.

The silk glands are supplied with small branches from the visceral trachea of the third abdominal segment.

The body muscles are chiefly tracheated by branches from the dorsal and ventral trachea of each segment.

Each male gonad (Fig. 5E and F) is supplied with two branches from the dorsal tracheae (1b,2b) of the fifth abdominal segment. Each female gonad (Gih. 5C) is supplied with two small tracheae, one arising from the posterior dorsal trachea (2b) of the fifth abdominal segment, the other from the anterior dorsal trachea (1b) of the sixth abdominal one.

The spiracles (Fig. 5G) are oval openings, each usually contained in a small sclerotic plate of the body wall forming a distinct spiracular sclerite or peritreme (Ptr). The first pair of spiracles is located posteriorly on the sides of the prothorax, while the seven following pairs are situated anteriorly on the sides of the first seven abdominal segments. The last pair, which is larger than the preceding spiracles, is located on the middle of each side of the eighth abdominal segment.

The atrial orifice is guarded by a filter apparatus consisting of two opposing rows of tapering processes projecting from the anterior and posterior walls of the atrium, thickly clothed with interlacing hairs.

The spiracular closing apparatus (Fig. 5H) includes a crescentic bar, and the closing bow (h). One estremity of the closing lever (l) is attached to the dorsal end of the closing bow. The closing lever is composed of two chitinous bars parallel to each other and run along a line joining the ends of the closing bow, to a point almost halfway between the ends of the bow. There they unite and then turn abruptly away from the centre of the trachea at almost a right angle. Between the apex of the lever and the ventral end of the closing bow, is a soft fold (k) called the closing band. There are two slender closing muscles (osp) extending between the free arm of the lever and the ventral end of the closing bow. These muscles cause the closure of the tracheal orifice by their contraction. There is a dorsal dilator muscle (d1sp) arising on the body wall and inserted on the lever, and a ventral dilator muscle (v1sp) inserted on the ventral end of the closing bow.

The structure of the tracheal closing apparatus is the same in the thorax and abdomen, except that the closing bow is anterior in the abdomen and posterior in the thorax.

The nervous system

Anterior to the origin of the circum-oesophageal connectives (Fig. 6B; CoeCon) and commissures (3 Com), three large nerves run forward along the pharynx. The outer one is the optic nerve (Fig. 6 A and B; OpNv) which innervates the ocelli. The middle one is the antennal nerve (Fig. 6A, AntNv) extending to the antenna. The inner one is the labral nerve which divides after a short distance from the brain into a frontal ganglion connective (Fig. 6 A; Fr Con) and a labral nerve (Fig. 6 A, LmNv) which proceeds anteriorly to the labrum. Besides the sub-oesophageal ganglion, the ventral nerve-cord (Fig. 5B,C,D:VNC) consists of ten ganglia, three of which lie in the thoracic segments, one for each segment. The other seven ganglia lie in the first sixabdominal segments, one for each segment except the sixth which contains two ganglia. The terminal ganglion, which lies in the sixth

abdominal segment, is the largest and represents the ganglia of both the seventh and eighth segments.

The sub-oesophageal ganglion (SoeGng) gives off four pairs of nerves; innervating the mandibles (MdNv), maxillae (MxNv), labium (LbNv) and the muscles of the neck region (v).

Each of the thoracic and first six abdominal ganglia gives off two pairs of anterior (2Nv) and posterior (3Nv) lateral nerves, which innervate the body muscles. Each of the anterior nerves (2Nv) of the mesothoracic and metathoracic ganglia

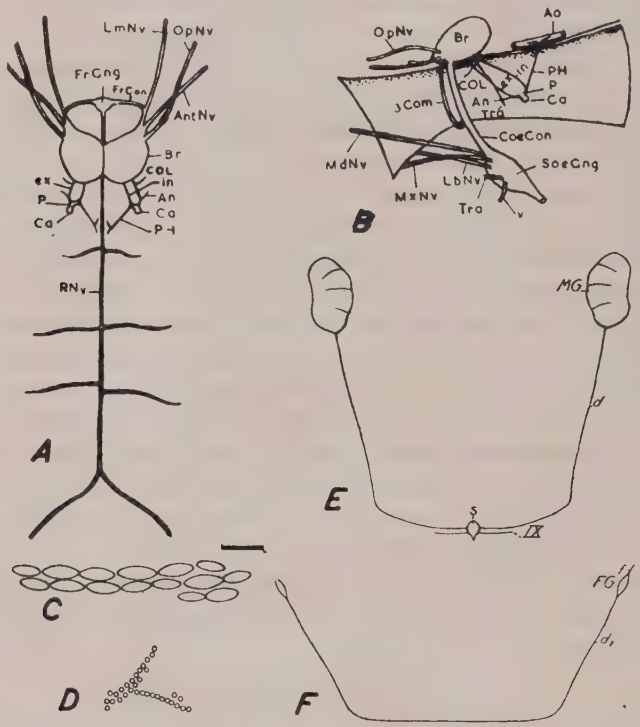

FIG. 6: A, dorsal view of brain and stomodaeal nervous system. —B, lateral view of brain, sub-oesophageal ganglion and stomodaeal nervous sytem. — C, the oenocytes of the right side of the eighth abdominal segment. — D, the ventral nephrocytes of the right side. — E, the male reproductive system. — F, the female reproductive system.

(An, anterior paracardial nerve; Ant Nv, antennal nerve; Ao, aorta; Br, brain; Ca, corpus allatum; Coe Con, circum-oesophageal connective; COL, collateral cyphalic nerve; 3 Com, sub-oesophageal commissure, d; d 1, fine strands; ex, external paracardial nerve; f, filament; Fg, female gonad; Fr Con, frontal ganglion connectives; FrGng, frontal ganglion; in, internal paracardial nerve; LbNv, labium nerve; LmNv, labral nerve; Md Nv, mandibular nerve; Mg, male gonad; Mx Nv maxillary nerve; Op Nv, optic nerve; P, corpus paracardiacum; PH paracardial- hypocerebral nerve; RNv, recurrent nerve; s, spherical body; Soe Gng, sub-oesophageal ganglion; Tra, trachea; V, ventral nerve of sub-oesophageal ganglion. Roman numbers refer to the abdominal segments).

gives off a branch extending anteriorly to unite with the lateral nerve (1Nv) of the ventral sympathetic nervous system. Each posterior lateral nerve (3Nv), arising from the thoracic ganglia, gives off a branch, to innervate the corresponding thoracic leg. The terminal ganglion, which is the fused seventh and eighth abdominal ganglia, gives off four pairs of lateral nerves.

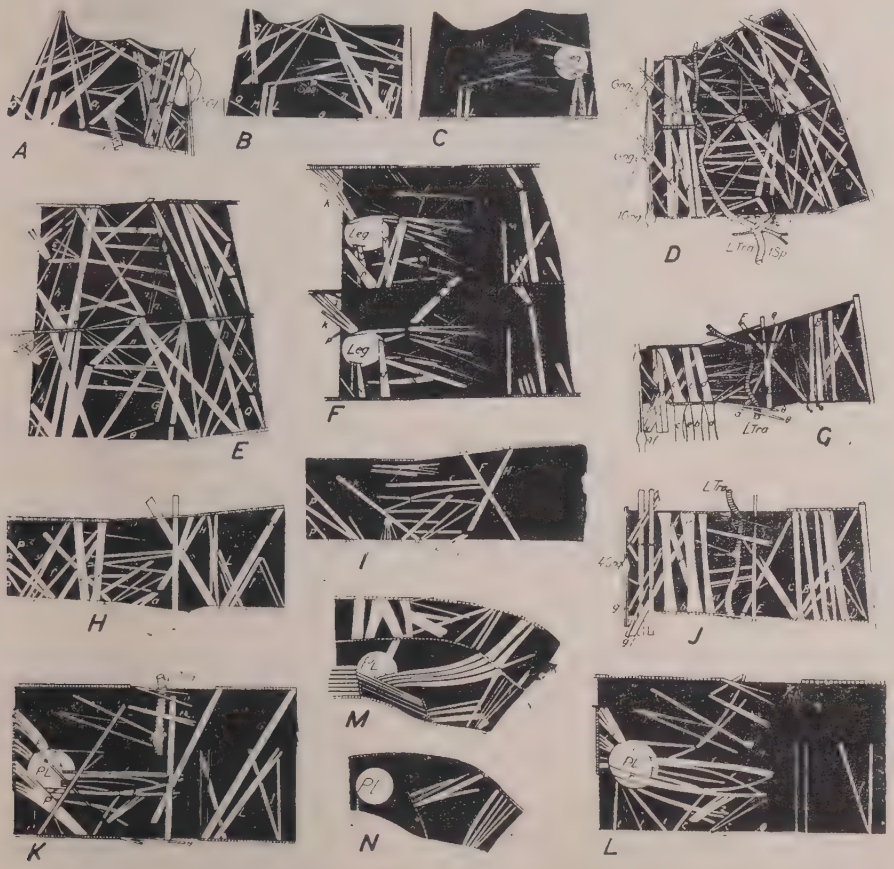

FIG. 7 : Body musculature. The muscles nearest to the body cavity appear superficial and the last layer of dissection represents the ones close to the skin. — A,B and C, muscles of prothorax dissected in three stages. — D,E, and F, muscles of mesothorax and metathorax dissected in three stages. — G, H, and I, muscles of first abdominal segment dissected in three stages. — J, K and L, muscles of fourth abdominal segment dissected in three stages. — M, muscles of the last two abdominal segments.

(Gng, ganglion; PL, proleg; PrG, repugnatorial gland; SpI, first abdominal spiracle).

Other lettering as in other Figures.

Adopting the nomenclature used by HINTON (1951), the stomodaeal nervous system (Fig. 6A and B) comprises : (1) The frontal ganglion (FrGng) connected

with the brain by the frontal ganglion connectives (FrCon). This ganglion gives rise posteriorly to the recurrent nerve (RNv). (2) The recurrent nerve passes backwards to the end of the crop and gives off along its course few lateral branches to the fore-gut and two nerves which diverge backwards along the surface of the proventriculus. (3) A pair of small ganglia, the corpus paracardiaca (P), lies on the sides of the oesophagus. Each ganglion is connected to the protocerebrum by the internal (in) and external (ex) paracardial nerve, and gives off a slender nerve, the paracardial-hypocerebral nerve (PH) to innervate the aorta. The anterior paracardial nerve or the collateral external ventral nerve (An) arises from the corpus paracardiacum and extends forewards. A lateral nerve, the collateral cephalic nerve (COL), arises from the external paracardial nerve near its base.

The ventral sympathetic nervous system (Fig. 5B,C) comprises a median nerve originating from the posterior part of each ganglion of the ventral nerve cord. The median nerve (MedNv) extends posteriorly between the longitudinal connectives and gives off a pair of lateral branches (INv) extending outwards to the neighbourhood of the spiracles. The median nerve divides into the lateral branches, a short distance in front of the succeeding abdominal ganglion.

The median nerve arising from the prothoracic ganglion extends a short distance behind it and gives off the lateral branches (INv) to meet those of the anterior lateral nerves (2Nv) of the mesothoracic ganglion. The median nerve originating from the mesothoracic ganglion proceeds posteriorly half way between the mesothoracic and metathoracic ganglia, then gives off the lateral branches to unite with those of the anterior lateral nerves of the metathoracic ganglion. The lateral branches (1Nv) of the last abdominal ganglion arise from its posterior region.

The muscular system

The head-capsule is provided on each side with oblique, fan-like muscles (Fig. 1B, m oc.f.) which are attached to the ventral postoccipital apodeme (vap). These muscles are extending dorsally and laterally to the lateral parts of the postoccipital ridge (PoR).

The antenna is moved by four slender muscles (Fig. 1F; m. ant) arising on the parietal walls of the cranium and are inserted anteriorly on the outer angle of the base of the proximal antennal segment.

The labrum is moved by a pair of retractor muscles. Each mandible is moved by two groups of muscles (Fig. 2B), the abductor group (ab.md) and the adductor group which is disposed in two unequal sets of muscles fibres (1ad. md, 2ad. md). The musculature of the maxillae (Fig. 2F, G, I) comprises muscles pertaining to its three parts. The cardo is provided with three adductor muscles (1ad. cd, 3ad.cd). The stipes is also provided with three adductor muscles (1ad. st-3ad. st). The free terminal lobe is moved by three muscles (Fig. 2H), the external and internal retractor muscles (ex. r. lc, in. r. lc) and the cranial abductor muscle (ab. lc) that moves the terminal maxillary lobe. The prelabium-hypopharynx, or the spinneret bearing

lobe (Fig. 2H, 1, J) is provided with two pairs of muscles (r. prmt, p. prmt). There are two pairs of dorsal muscles (d.pr) arising on the dorsal arms of the prementum and inserted on the dorsal wall of the silk-press. There is also a pair of ventral muscles (v. pr) which arises on the ventro-lateral parts of the prementum and is inserted on the dorso-lateral edges of the silk-press.

For distinguishing the body muscles, the lettering of LYONET for the somatic muscles of caterpillars, as mentioned by FORBES (1914), is adopted in this work as shown in Figure 7.

The body muscles of the prothorax (Fig. 7A, B, and C) differ greatly from those of the mesothorax and the metathorax (Fig. 7D, E, and F) which are nearly alike and differ also from those figured by FORBES (1914). Therefore, they are labelled by comparison with those of the other two segments of the thorax. The muscles which have been found but could not be given the appropriate lettering, are shown in the Figure unlabelled.

The first eight abdominal segments are nearly alike in their body musculature. Therefore, the muscles of the first and fourth abdominal segments (Fig. 7, G,H, I,J,K, and L) may be taken as typical for the other segments.

Towards the posterior end, reduction is progressive to the last two segments (Fig. 7M, and N). The musculature of the last segment shows that the segment might have been the result of the fusion of two segments.

The coxa of the thoracic leg (Fig. 3C, and D) is provided with two protractor muscles (p. cx), a single retractor muscle (r.cx), a posterior rotator muscle (p.ro.cx), an anterior rotator muscle (a.ro.cx) and three abductor muscles (ab.cx). The trochanteral muscles consist of three short levator muscles (1.tr), two long depressor muscles (d.tr) and another two short depressor muscles (2d.tr). The femur is provided with a short reductor muscle (rd.fm.). The tibia has a levator muscle (1.tb) and three depressor muscles (d.tb). The tarsus is provided with a single depressor muscle (d.tar). The pretarsus is provided with depressor muscles only (d.ptar), which are inserted on a long slender tendon (x) that traverses the tarsus to its attachment, ventrally on the base of the pretarsus.

The musculature of each of the first four pairs of prolegs (Fig. 3H,1) is similar and consists of two sets of muscles (a, b and c). The plantar muscles of the last pair of prolegs (b and c) consist of six muscles.

The circulatory system and associated structures

The dorsal vessel extends from the eighth abdominal segment to end beneath the brain. The enlarged part between the closed caudal extremity and the thorax is the heart (Fig. 5C, and D). Inside the thorax, the vessel narrows considerably to form the aorta (Fig. 5A). Fan-shaped alary muscles (Fig. 5C,am) are attached along either side of the heart.

In addition to the dorsal pericardial cells, which are present in the pericardial sinus, there are two groups of spherical cells located in the prothorax neighbouring

the spiracles and the mandibular glands. The cells of each group are arranged in a chain-like (Fig. 6D) and each cell is about 65 μ in diameter.

As in all insects, the two regions of fat-body are distinguished. The first region is the parietal zone which lies between the epidermis and the muscles of the body-wall. The second region is the main mass of fat-body, which occurs in thick clumps around the different systems in the visceral sinus.

The oenocytes

The oenocytes (Fig. 6C) are large, oval cells arranged in chains in the body cavity. They extend under the body-wall from the spiracular tracheae to near the mid-ventral line. Each cell is about 240 μ high and 160 μ broad.

The reproductive system

The gonads occur on the dorsal side of the fifth abdominal segment along the sides of the heart and directly underneath the body-wall. The male gonads (Fig. 6E; MG) are whitish, kidney-shaped organs, divided into four parts by three transverse constrictions. Each gonad is about 2.5 mm. long and 1.5 mm. wide. From the posterior end of each gonad a fine strand (d), which may be the future vas deferens, proceeds backwards until it reaches the tracheae near the eighth abdominal spiracle where it turns mesally and posteriorly to end in a spherical body (s) measuring about 0.4 mm. in diameter. The spherical body is located ventrally at the middle of the posterior margin of the eighth abdominal segment. A minute membranous strand with chitinized markings in its walls, proceeds posteriorly from this spherical body to the anterior part of the ninth abdominal sternum.

The female gonads (Fig. 6F), each measuring about 0.7 mm. long, are small, spindle-shaped bodies and opaque whitish in colour. A fine strand (d) which appears to be the future oviduct, makes its appearance at the posterior end of the female gonad. The fine strand runs backwards and downwards until it reaches the tracheae near the seventh abdominal spiracle, where it turns mesally to the centre of the seventh abdominal sternum to meet a corresponding one from the opposite side.

V. ACKNOWLEDGMENTS

Many thanks are due to Dr. A.D. Hanna and Mr. A. Alfieri for their valuable advice and help during the progress of this work.

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FURTHER EXPERIMENTS ON THE CHEMICAL CONTROL OF *THRIPS TABACI* LIND. AND OTHER INSECT PESTS INFESTING COTTON SEEDLINGS

(with 1 Text-Figure and 4 Tables)

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CONTENTS

I. Introduction. — II. Materials and procedure. — III. Experimental design. — IV. Estimation of control effects and interpretation of data. — V. Results. — VI. Discussion. — VII. Summary. — VIII. Acknowledgment. — IXX. References.

I. INTRODUCTION

In a previous paper ABUL-NASR and EL-NAHAL (1957) reported on the results of field experiments conducted during 1956 to evaluate some new synthetic organic insecticides, used as sprays, for the control of the onion thrips, *Thrips tabaci* Lind., infesting cotton seedlings. This work was the first part of a research program for the control of early-season cotton pests. The insecticides tested were: Dieldrix 15, Folidol E 605, Gusathion, Chlorthion, Diptrex, Metasystox, Gammaline, Agrocide and Nicotine sulphate.

The present work is a continuation of the above mentioned program. It presents the results of further spraying tests carried out during 1957 with some other insecticides for the purpose of evaluating them and comparing them with some of those used in the previous season. Another purpose of these present tests is to determine the proper timing and number of applications necessary for successful control. The insecticides used are: Toxaphene, HOE 2671, DDT plus Lindane,

Gusthion, Metasystox and Gammaline. Instead of Dieldrix 15 which was used last season, a 50% wettable powder of Dieldrin was chosen.

Bayer S 276 (Disyston) and American Cyanamid 3911 (Thimet 44-D), two systemic insecticides formulated as powders for seed treatment, were also tested. The seed treatment method has been recently developed by Ivy et al (1950, 1952, and 1953), who proved it to have more advantages over the other convential methods, such as dusting and spraying, for the control of early-season cotton pests.

The present experiments were mainly intended for thrips control, but effects on aphids and spider mites were also observed. The results concerning aphids, although they are not very info mative due to the scarcity of infestation, will be reported herein, but those of spider mites will be the subject of a further communication. Owing to the common scarcity of the cutworm, *Agrotis ypsilon* Rott. and the springtails in all the experimental plots including the controls, data concerning these two pests could not be gathered.

II. MATERIALS AND PROCEDURE

A. Seed treatment experiments

Two insecticidal formulations were used: (1) Disyston, a seed powder containing 50% phosphorodithioic acid S-2 (ethylthio) ethyl 0,0-diethyl ester and activated carbon as the carrier (supplied by Bayer, code designation in Germany S276); (2) Thimet 44-D, a powder containing 44% actual thimet (0,0, diethyl S-(ethythiomethyl phosphorodithioate) and 2% methylcellulose (supplied by the American Cyanamid Co., old Bayer code designation L. 11/6, A.C.C. code designation 3911).

Each of the two powders was used at 3 rates which were chosen to be around the recommended rates of the Manufacturers. These rates are given in Table II.

The seeds used were of the ashmuni variety. A sufficient quantity was first cleaned, and weighed lots were treated as follows:

Each lot, after being slightly moistened with water in order to decrease the dustiness of the finished product, was put in a cylindrical glass jar together with the weighed dose of the insecticide. The jar was then stoppered and shaken vigorously for about 5 minutes until the seeds were thoroughly coated. Treated seeds were sown and irrigated on the same day.

B. Spraying experiments

The insecticidal formulations used for spraying were as follows :

1. — Toxaphene emulsion concentrate containing 60% actual toxaphene and 6% emulsifier; (2) HOE 2671, an emulsion concentrate containing 20% of Hexachloroendomethylen-bis-cyclohepten-bis-(oxymethylen) sulfit, 70% zylol and 10% oxethylated alcylphenol as a sticking material (supplied by Hoecht. Frankfurt, Germany); (3) DDT – Lindane emulsion, an emulsion concentrate containing 30%

DDT and 9% Lindane; (4) Gusathion, (5) Metasystox, and (6) Gammaline (for active ingredients and formulation see ABUL-NASR and EL-NAHAL, 1957); (7) Dieldrin wettable powder containing 50% actual Dieldrin.

The rates at which these insecticides were used are given in Table IV. The diluted preparations were sprayed in the same way and at the same rates per acre followed by ABUL-NASR and EL-NAHAL (1957).

III. EXPERIMENTAL DESIGN

The experiments were carried out in two fields (A and B). Field A was 2 acres. It was divided into 10 plots of 1/5 acre each, and were given the numbers 1A to 10A. Plot number 1A was divided into 3 sections and was cultivated with seeds treated with Thimet 44-D at 3 rates as shown in Table II. The rest of the plots were devoted for spraying experiments with the different insecticides as shown in Table IV, leaving 2 plots (2A and 6A) as controls.

Cultivation of field A took place on the 7th of March.A part from the irrigation given on the same day of cultivation, only one more irrigation was given during the whole period of the experiments, that on the 19th of April, i.e. 42 days after cultivation.

Two sprayings were made, the first was on April 2nd, and the second on April 25th.

Field B was about 200 meters far from field A, and was also 2 acres large. Out of this area only two plots (1B and 2B), 1/4 acre each, were treated and the rest of land was left as control (3B). Plot 1B was divided into 6 sections which were cultivated with seeds treated with Thimet 44-D and Disyston at the rates given in Table II. The rates of Thimet 44-D were the same as those used in field A. Plot 2B was sprayed only once with Dieldrin wettable powder at the same dilution used in field A.

Cultivation of field B took place on March 13th, i.e., about a week later than field A. Apart from the irrigation given on the same day of cultivation two other irrigations took place during the period of the experiment; the first on March 29th, (16 days after cultivation) and the second a month later on April 29th.

IV. ESTIMATION OF CONTROL EFFECTS AND INTERPRETATION OF RESULTS

Results of treatments were evaluated by counting the adults and nymphs of thrips and also aphids in representative samples of 20 plants from each plot including the control plots. These counts were carried out on occasional intervals before and after treatments, as indicated in Tables I, II and IV. The percentages

reduction of thrips population resulting from any given treatment were calculated from the number found on treated plants with the representative number found on the plants of the control plot (see ABUL-NASR and EL-NAHAL, 1957).

Counts of thrips and aphids in the control plots of two fields were carried out continuously throughout the whole period of the experiments in order to show the course of the natural infestation. On the account of the natural infestation, the timing of the two sprayings was determined according to reasons that will be explained later.

V. RESULTS

A. Population trends in 1957

A. Thrips population

Thrips counts in the control plots 2A, 6A and 3B are recorded in Table I and shown graphically in Figure 1. If these counts were compared with those of last season the following informations can be deduced :

TABLE I

Changes of thrips and aphids population on cotton plants in 3 control plots, in 1957.

Date	Number of thrips and aphids per 20 plants								
	Plot 2A			Plot 6A			Plot 3B		
	Thrips		Aphids	Thrips		Aphids	Thrips		Aphids
	Nymphs	Adults		Nymphs	Adults		Nymphs	Adults	
March 21st	0	24	40	0	29	—	—	—	—
March 23rd	0	16	80	0	23	40	—	—	—
March 26th	32	28	32	41	21	21	0	16	26
March 30th	156	0	6	139	0	9	4	4	10
April 1st	146	0	0	126	0	0	—	—	—
April 3rd	89	1	1	82	2	2	53	10	7
April 7th	2	1	1	9	1	1	77	1	0
April 11th	0	4	1	2	6	1	7	0	0
April 15th	2	9	2	0	7	0	2	10	0
April 20th	0	42	0	8	82	0	4	44	0
April 24th	—	—	—	22	50	0	—	—	—
April 27th	12	26	0	32	60	0	54	60	0
May 2nd	216	40	16	216	32	8	—	—	—
May 5th	—	—	—	—	—	—	190	14	2
May 7th	86	24	2	36	62	3	110	40	0
May 11th	6	10	0	—	—	—	6	14	0
May 12th	—	—	—	16	36	0	—	—	—

1. — The degree of thrips infestation in 1957 was considerably lighter than in 1956. The maximum number of nymphal thrips counted on 20 plants in 1956 was 324 whereas the maximum number in 1957 never exceeded 218 nymphs.

(2) As in 1956, two peaks of larval population occurred during March, April and the first half of May. The first peak was reached in field A at about the 30th of March, and then declined and ended at about the 7th of April. The second peak was reached at about the 2nd of May. The same trend of thrips population was shown in field B except that the first peak took place about the 7th of April; a week later than in case of field A.

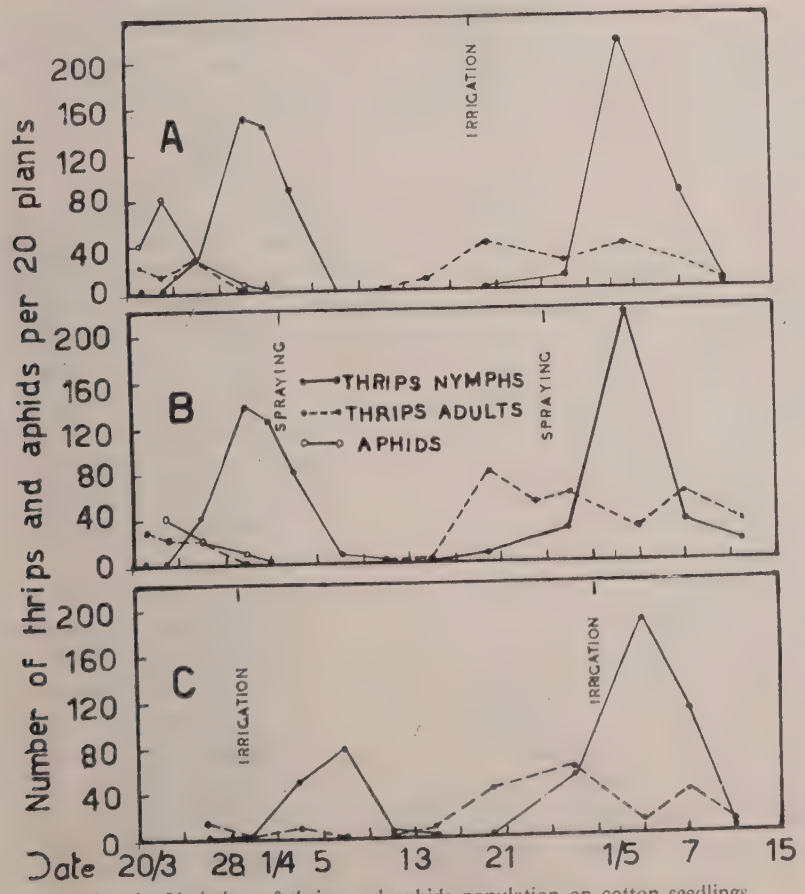

FIG. 1 : Variation of thrips and aphids population on cotton seedlings from March 20th till May 15th, 1957.

The different feature in nymphal thrips curves in 1957 season is their shorter duration than in 1956 and this caused the period between them to become longer.

3. — By comparing the curves A and B (Fig. 1) which represent the condition of thrips infestation in two sites of same field with C which represents the infestation in another field no considerable variation is noticed. The variation found is the delay and low numbers of the first nymphal peak in field B. This might be due to the fact that field B was cultivated a week later than field A, and accordingly the cotton seedlings were not as equally exposed to the adults preceding this peak as those of field A.

(4) The curve of the adults is quite different from that of the nymphs, and it shows an increase lagging behind the larval peaks.

b. Aphids population

Aphis infestation was generally very light throughout the period of the experiments, except for a short period after the beginning of planting (Fig. 1A and B). Even during this period the maximum number of aphids per 20 plants did not exceed 80.

B. Seed treatment experiments

The two insecticides used for seed treatment, Thimet 44-D and Disyston showed high insecticidal efficiency even with the lowest rates used (Table II). In plot 1A the seedlings remained free from infestation with nymphs and adults of thrips and aphids for 4 weeks, i.e. from March 17th, the date of complete emergence of plants, till April 14th. A few adult thrips appeared on the plants on April 15th. Starting from April 20th, nymphal thrips began to appear in very low numbers as compared with the numbers found on the untreated plants of the control plot 2A.

Thus, it could be said that the treated plants in plot 1A escaped from the first nymphal thrips peak, and were very slightly affected with the second peak.

In plot 1B, which was treated with Thimet 44-D and Disyston (Table II), the plants also remained free from infestation with thrips and aphids for about 4 weeks, i.e. from March 21st, the date of complete emergence, till April 20th. In the two counts made on April 20 and April 27, very few adults appeared on the plants specially in the Disyston plot. Later on, very few nymphs were occasionally found. It could be stated that the effect of the two seed powders in plot 1B covered the period of the two thrips nymphal peaks. This variation in results of the two fields might be due to the different timing of irrigation followed in the two fields. As previously mentioned, field B was given two irrigations, the first was prior to the first peak of the nymphal thrips and the second irrigation took place at the start of the second peak. In field A the one irrigation given was on a date between the two peaks.

In both plots, 1A and 1B, the three rates used of the two seed powders seemed to give no appreciable difference on the results. The lowest rates gave nearly the same results as the highest.

It should be mentioned here that in no case was there any injurious effect of thrips apparent on the plants of treated seeds, whereas thrips damage started to

TABLE II — *Effectiveness of Thimed* 44-D *and Disyston as cotton seed treatments against thrips and aphids in field experiments (no infestation appeared on the plants of treated seeds from March 21st. till April 15th.)*

Plot number	Insecticide	Dose per 100 kilos of seeds	Number of thrips and aphids per 20 cotton seedlings																												
			April 15th.			April 20th.			April 27th.			May 2nd.			May 3rd.			May 7th.			May 11th.			May 16th.								
			Thrips		Aphids	Thrips		Aphids	Thrips		Aphids	Thrips		Aphids	Thrips		Aphids	Thrips		Aphids	Thrips		Aphids	Thrips		Aphids						
			Nymphs	Adults		Nymphs	Adults		Nymphs	Adults		Nymphs	Adults		Nymphs	Adults		Nymphs	Adults		Nymphs	Adults		Nymphs	Adults						
		Kilos																													
		4.5		14		2	20		8	118		74	36	6	—	—	—	10	24			2		1	16						
1A	Thimet 44-D	6.5		4			46			10		70	28		—	—	—	4	56	2		20		4	10						
		8.5		14			38			140		16	24	2	—	—	—	8	38			4		3	8	1					
2A	Control	—	2	9	2		42		12	26		216	40	16	—	—	—	86	24	2	6	10		5	4						
		4.5					4			4		—	—	—		32		4	14		6	36		7	6						
	Thimet 44-D	6.5										—	—	—	4	8			18			4			2						
		8.5										—	—	—		2			34			2									
1B		6.0								14		—	—	—	6	42			12		2	20		3	1						
	Disyston	8.0		12			2			4		—	—	—		14		4	30			6			2						
		10.0					6			28		—	—	—	2	22		2	46		2	8			3						
3B	Control		2	10		4	44		54	60		—	—	—	190	14	2	110	40		6	14		41	2	1					

appear on the untreated plants very early in the season. Table III shows degree of damage caused by thrips to the plants of the control plots. The percentages recorded in that Table were obtained from samples of 100 plants.

TABLE III

Percentages of thrips injured plants in control and seed treatment plots

Date	Percentages of thrips injured plants		
	Plot 2A	Plot 3B	Seed treatment plots (1A and 1B)
March 30th.	40	85	0
April 3rd.	50	100	0
April 7th.	65	100	0
April 11th.	95	100	0
April 15th.	100	100	0

Starting from about the 15th of April, symptoms typical to those caused by springtails were apparent on the plants of plot 3B, whereas the plants of plot 1B were quite free from such symptoms. These symptoms were described by WILLCOCKS and BAHGAT (1937). This observation might indicate the insecticidal effect of Thimet 44-D and Disyston on the springtails as well. No records of population of this pest were taken in this work.

C. Spraying experiments

a. Thrips

Thrips population counts made before and after each of the two sprayings given in field A are arranged in Table IV. The calculated percentages reduction in nymphal thrips population due to the effect of the insecticides are also given in the same table. From these records the following deductions could be presented:

1. — After the first spraying all the insecticides used showed complete initial kill of thrips nymphs and adults as indicated by the counts made the day after spraying. The plants then remained free from thrips for about 19 days, after which nymphs and adults started to appear. This coincided with the start of the second peak of nymphal population.

2. — After the second spraying the same results of initial kill as happened after the first spraying were also obtained, but the residual effect varied. After 7 days from spraying, thrips nymphs started to appear on the plants treated with Gusathion DDT – Lindane, HOE 2671 and Gammaline whereas the plots treated with Dieldrin, Toxaphene and Metasystox continued to be almost free till the end of the 2nd peak of nymphs.

TABLE IV: *Effectiveness of various chemicals used as sprays against thrips in field experiments in* 1957.

Plot number	Insecticidial formulation and percentage of active ingredient	Rate of dilution	Number of thrips per 20 plants and percentage reduction in thrips nymphs																													
			1st April		First spraying (2nd April)																		Second spraying (25th April)										
					3rd April			7th April			11th April			15th April			21st April			24th April			27th April			2nd May			7th May				
			Nymphs	Adults	Nymphs	% red.	Adults	Nymphs	% red.	Adults	Nymphs	% red.	Adults	Nymphs	% red.	Adults	Nymphs	% red.	Adults	Nymphs	% red.	Adults	Nymphs	% red.	Adults	Nymphs	% red.	Adults	Nymphs	% red.	Adults		
3A	Toxaphene E.C., 60%	1000 cc. per 100 l.			0	100	0	0	100	0	0	100	0	0		0	0		14	0		27	0	100	0	0	100	0	0	100	0		
4A	Gusathion E.C., 20%	200 cc. per 100 l.			0	100	0	0	100	0	0	100	0	0		0	2		18	11		38	0	100	0	52	85	44	26	28	6		
5A	DDT(30%) +Lindane 9% E.C.	110 cc. per 100 l.			0	100	0	0	100	0	0	100	0	0		0	2		66	13		52	0	100	0	138	37	46	37	0	6		
6A	Control		126	0	82		2	9		1	2		6	0		7	8		82	22		50	32		60	216		32	36		62		
7A	Gammaline E.C., 20%	100 cc. per 100 l.			0	100	0	0	100	0	0	100	0	0		0	8		20	18		45	0	100	0	190	12	54	41	0	0		
8A	HOE 2671 E.C. 20%	200 cc. per 100 l.			0	100	0	0	100	0	0	100	0	0		0	6		14	13		39	0	100	0	144	53	22	28	22	2		
9A	Metasystox E.C., 50%	100 cc. per 100 l.			0	100	0	0	100	0	0	100	0	0		0	2		36	7		57	0	100	0	2	99	16	4	89	8		
10A	Dieldrin, W.P., 50%	200 grs. per 100 l.			0	100	0	0	100	0	0	100	0	0		0	0		6	0		32	0	100	0	0	100	0	0	100	2		

From the foregoing explanation, it would be suggested that the insecticides used showed a longer residual effect after the first spraying than after the second spraying. However, if we take into consideration the different conditions of natural infestation that prevailed after each spraying, the situation might be changed. The first spraying was made after the thrips nymphal population had reached the climax of the first peak. At the end of this peak, which continued only for about 6 days after spraying, even the untreated plants were quite free from thrips nymphs. Therefore the absence of the insects on the treated plants during this period could not be attributed to the effect of the insecticides. On the other hand, the second spraying was made just at the start of the second peak of thrips nymphs. This peak lasted for about 18 days after the date of spraying and accordingly the timing of this spraying provided a reasonable period of infestation for determining the actual residual effect of the insecticides under test. On the seventh day after this treatment, Gammaline became almost inffective, DDT + Lindane and HOE 2671 lost about 65% of their effect, Gusathion was still highly effective (85%), Dieldrin, Taxaphene and Metasystox were still 100% effective.

On field B, plot 1B was sprayed once only with Dieldrin wettable powder (50%) at the rate of 200 grams per 100 litres. At the time of spraying, the plants were quite free from thrips nymphs, and were still in the dicotyledonous leaves stage. No counts of thrips were taken for this plot and only observations on the appearance of thrips damage were made and compared with the untreated plants. As expected the damage appeared very late at the start of the second peak of nymphs.

b. Aphids

No infestation with aphids appeared in all the sprayed plots throughout the whole period of the experiments. Also in the check plots the infestation was almost negligible except, as mentioned before, during a short period before the first spraying. No difinite conclusions could therefore be made for aphids.

VI. DISCUSSION

In a previous conmmunication, Abul-Nasr and El-Nahal (1957) reported on experimental work carried out in 1956, in which the authors evaluated eight new synthetic organic insecticides and Nicotine sulphate for the control of onion thrips, *Thrips tabaci* Lind., on cotton seedlings. In addition they clarified that during March, April And the first days of May, there exist two peaks of nymphal thrips population which are responsible for most of thrips damage caused to cotton seedlings during this period.

With that work as a basis, further investigation was necessary to determine the proper time for the control of the pest, and also to determine the proper number of applications necessary for successful and economical control. Because Dieldrin,

Gusathion, Metasystox and Gammaline gave promising results last season, they were re-selected for the present investigation. Toxaphene, DDT + Lindane and HOE 2671 emulsions and two seed powders, Thimet 44-D and Disyston were included for evaluation and for comparison with the other insecticides used.

It was felt necessary that a more detailed study of the fluctuations of thrips population, specially the nymphs, throughout the period of the experiments should be made to find out if there is any variation in the trend of population from one season to another and to design a schedule for timing the application of the insecticidal sprays according to the nature of the infestation. Also it was hoped to study the control effects of the tested insecticides against other pests mainly aphids *Aphis gossypii* Glover.

The studies of changes in thrips population have confirmed the presence of two peaks of nymphs from March until the middle of May, but this season, the infestation was light. This might be due to the unfavorable weather conditions that prevailed during the period of investigation. According to the monthly reports of the Central Agro-Meteorological Station, Plant Breeding Farm of Giza, an outstanding heat-wave of the khamasin type manifested itself in the period from 12th to 16th of April, reaching its climax on the 15th, giving an absolute maximum temperature of 40.3°C. Such temperature is above the thermovital zone of this insect which, according to GHABN (1948), lies between 8 and 38°C.

The results of the experiments of seed treatment with Thimet 44-D and Disyston indicate that this method is very promising for the control of cotton seedlings pests, at least from the points of view of thrips and aphids throughout the early season insect control period. These findings are in accord with the findings of other workers who carried out similar studies. According to the Annual Report on Conference on Cotton Insect Research and Control "Memphis, Tenn., 1955 (2)", "Thimet in laboratory killed thrips, spider mites, the cotton aphid, the boll weevil, and the cotton leaf perforator for 4 to 9 weeks following emergence of the seedling plants. In the field it was effective 4 to 6 weeks. However, under some conditions it may adversely affect germination of seeds, and there is some evidence that this chemical exerts certain physiological effects on plants that are not well understood". Also PARENCLA et AL (1957) reported on the results of tests with the American Cynamid 3911 applied as a seed treatment at 1 pound per acre and concluded that this treatment afforded protection against thrips, cotton aphid and other pests throughout the early season insect control period in central Texas.

The only available reference on Disyston is the Circular letter No. 4B of the Farbenfabriken Bayer 20. According to this reference, tests carried out by IVY, and MERKL, working seperately, proved the equal effectiveness of Disyston and Thimet 44-D for the control of cotton aphid and thrips infesting cotton seedlings.

Although the present experiments have demonstrated the high effectiveness of the two seed powders against the early season cotton pests, but their use in large scale control should be fitted to the requirements of safety and phytotoxicity.

According to Thimet Insecticide Technical Manual "the biological effect of Thimet is the same as that of other phosphate ester insecticides. By skin absorption, it might be somewhat less toxic than parathion, and by all other routes of exposure, the degree of toxicity and hazard are closely similar to parathion". Also, it has been stated that under good conditions of soil no effects of treatment with Thimet 44-D has been noted on seed and seedling vigor. On the other hand, according to Bayer Circular letter No. 4B, Disyston has the great advantage of a considerably lower toxicity to warm blooded animals and a much better plant compatibility so that injuries during emergence of the treated seeds and depressions of the growth are not to be expected.

No accurate studies on the effects of these chemicals on germination or growth have been made in this investigation. Only observations made ten days after cultivation in all treatments and check plots revealed no appreciable effects on germination and no decrease in stand. The growth of the plants of treated seeds was apparently better, due perhaps to their escape from infestation.

The results of spraying experiments, reported in this paper proved that all the insecticidal sprays at the chosen dilutions (Table IV) gave complete initial effect but they varied in respect to their residual effect. Dieldrin, Toxaphen and Metasystox showed the longest effect. The others arranged in a descended order are: (1) Gusation; (2) HOE 2671; (3) DDT+Lindane; and (4) Gammaline.

In the light of the study of the variation in thraps population, specially the nymphs, the two sprayings were conducted for two causes; the first spray as an eradicant and the other as a protectant. The first spray was applied when nymphal thrips population was reaching the top of the first peak. This was adopted because under practical conditions, sprays are usually applied when thrips popuation become so noticable and some injury already has occurred. The second spraying; the protectant, was carried out when the nymphs started to reappear after they had almost vanished during the period between the two peaks. By this it was meant to prevent severe infestation during the second peak.

Better results were obtained by the protectant spraying, using the insecticides of long residual effect. Further evidence relating to the good effects of the protectant spraying was gained by a test conducted in a plot in which a spray was applied very early while the plants were still in the dicotyledonous leaves stage, and before the appearance of any thrips nymphs. Only adults were there, undoubtedly, feeding and laying eggs. The insecticide used was Dieldrin wettable powder (50%) at a dilution of 200 grams per 100 litres. In this plot the plants escaped the first peak of nymphs and no obvious symptoms of thrips injury appeared until about the start of the second peak. Even during this peak the degree of infestation in this plot was not as severe as the check plot in the same field.

From the foregoing discussion, it appears that a protectant program of one application at about the time the adults of thrips start to appear on cotton seedings, followed by a second application if the nymphs start to appear again, would be

satisfactory. Whether this program is economical or not, depends on the forecast of the infestation. This suggests the desireability of further accurate ecological investigations concerning the different factors responsible for the seasonal variations in the degree of thrips infestation. Also the question arises as to whether there will be any increase in the yield per acre. Further large scale experiments are necessary before any definite conclusions could be made on this point. Evidently, the cotton seedlings during their early growth are very delicate and any factor that might retards their growth mostly influences their future growth and yield. According to GHABN (1937), the retardation of growth of cotton plant might increase their degree of infestation by *Prodenia litura* F. due to continuation of the vegetative growth for a longer time and in such a condition which makes them susceptible to this cotton worm.

VII. SUMMARY

Two seed powders, Thimet 44-D used at 4.5, 6.5 and 8.5 kilos per 100 kilos of seeds, and Disyston used at 6, 8 and 10 kilos per 100 kilos of seeds were tested against thrips and aphids infesting cotton seedlings. The two insecticides showed equal high efficiency in controlling these pests for about 4-7 weeks after emergence, with no appreciable difference between the three rates used for each one.

Studies on thrips population changes in untreated plots revealed that most of the damage caused to cotton seedlings by this pest during March, April and the first half of May is due mainly to two peaks of nymphal thrips population which vary in their magnitude from season to season.

On the basis of the variations in thrips population, two sprayings with 7 insecticides were conducted, one spraying as an eradicant and the other as a protectant. The insecticides tested are emulsion concentrates of Toxaphene (60%) at a dilution of 1000 cc./100 litres, DDT (30%) + Lindane (9%) at 110 cc./100 litres, HOE 2671 (20%) at 200 cc./100 litres, Gammaline (20% Lindane) at 100 cc./100 litres, Metasystox (50%) at 100 cc./100 litres and Gusathion (20%) at 200 cc./100 litres and also a 50% wettable powder of Dieldrin at 200 g./100 litres.

All the seven insecticides at the mentioned dilutions gave complete effect as eradicants, but as protectants Dieldrin, Toxaphene and Metasystox were more satisfactory, followed by Gusathion, HOE 2671 and Gammaline.

On discussing the results of changes in thrips population and spraying, a program of spraying has been suggested according to which satisfactory results are achived by a protetant aplication given shortly at the start of the first nymphal peak, followed, if necessary by an eradicant application when the nymphs of the second peak become noticeable.

Because aphid population was very low during the course of this work, the data concerning the control effects of the tested insecticides against this pest are not very informative.

VIII. ACKNOWLEDGMENT

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BIOLOGICAL STUDIES ON THE DIAMOND-BACK MOTH, *PLUTELLA MACULIPENNIS* CURTIS

[*Lepidoptera*: *Plutellidae*]

(with 3 Text-Figures and 8 Tables)

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INTRODUCTION

The diamond-back moth has an unusual wide geographical distribution. Its economic importance lies in the fact that it is very destructive to vegetables and to cruciferous crops. It can flourish in all climates and appears to be extending its range through the agency of commerce. Its damage in some countries lies in a small proportion and sometimes it has an outbreak and much damage is done. The most favourable areas for its multiplication appear to be in the sub-tropics and warmer temperate zones; even in the cool or temperate countries, the climate would allow an indefinite increase of this pest.

The diamond back moth is a seasonal pest and common in Egypt where it has been collected from various cruciferous, vegetables, weeds and some ornamental and green house plants. Occasionally, it occurs in enormous amount and its caterpillars then cause very serious damage to cabbage, cauliflower, turnips and other kind of cruciferae. It is particularly troublesome to vegetables grown in the Delta.

Although we have no accurate records of the first appearance of this pest in Egypt, it is certain that it has been present for long ago.

Investigations carried out by the present author deal with the biology of this pest under Egyptian environmental conditions, the factors affecting the insect development, its fecundity and its natural parasites. This work was carried out at Shebin El-Kom (Mounofieh) during 1952, 1953 and 1954, and at Kobbeh (Cairo) during 1956.

MATERIAL AND TECHNIQUE

Larvae and pupae collected in the fields on cabbage and turnips were brought to the laboratory and placed in screen cages and some in glass vials plugged with cotton. As moths emerged, females and males were selected each day and pairs of same were isolated separately in the vials which were provided with small cabbage leaves. The dimensions of the vials used were 4 inches in high and one inch in diameter, and each was covered by a closely fitting metal cap. The exposed cabbage leaves were renewed at daily intervals and the eggs laid during each interval were counted under a binocular microscope. Moths were also placed in oviposition screen cages of various sizes covered with gauze. The oblong cages proved to be most satisfactory as to egg production. It was found advisable to increase the humidity by introducing stripes of paper seaked in water, and food was supplied by the way of cotton wool seaked in honey water.

Incubation and hatching of the eggs were observed by transferring the eggs to potted cabbage plants in lamps chimney cages covered with gauze or cloth held in place by rubber bands. Each plant was examined daily until the eggs hatched and a record was kept for each pot.

Larval molts and instars were observed by placing the newly hatched larvae in lamp chimney cages or in cages supplied with cabbage leaves in small vials. The exposed leaves were removed from time to time and replaced by fresh ones. Daily observations were made, in which molting was recorded and the body and head casts were removed.

For studying the larval instars, all larvae which hatched in the same day were collected and kept in groups of ten in lamp chimney cages on potted small cabbage plants provided with labels showing the date of hatching. All larvae which moulted on the same day were separated again in groups of ten and placed on fresh plants and so on until pupation occurred.

For studying the pupal stage, the larvae were allowed to pupate in jars fitted with muslin or placed in vials plugged with cloth covers. These were examined daily, and records of the number and sex of the emerged moth were kept.

BIOLOGY

Emergence of the moths takes place during the early evening. Mating does not occur on the night of emergence, but in the following afternoon. It has been observed only under cage conditions, the male sometimes mating with two different females.

The average duration of the pre-oviposition period, oviposit on period and longevity of females and males are given in Table I.

TABLE I

The pre-oviposition period, oviposition period and longevity of females and males in 1953-1954

Month	Number of females		Average duration of pre-oviposition period in days		Average duration of oviposition period in days		Average duration of post-oviposition period in days		Average longevity of females		Average longevity of males	
	1953	1954	1953	1954	1953	1954	1953	1954	1953	1954	1953	1954
April .	6	9	2.3	2.4	6.5	6.2	1.5	1.8	10.3	10.0	15.4	13.0
May ...	22	18	2.1	1.9	5.2	5.1	1.4	1.5	8.7	8.5	12.2	11.1
June ...	16	24	2.2	1.4	4.2	3.5	0.5	0.8	5.9	5.7	6.3	7.2
July ...	20	12	1.4	1.6	4.4	4.1	0.6	0.7	6.4	6.6	6.9	8.3
Aug. ...	18	—	1.7	—	5.9	—	0.9	—	8.5	—	7.9	—
Sept. ...	15	—	1.9	—	5.8	—	0.7	—	8.3	—	8.5	—
Oct. ...	18	—	2.1	—	5.9	—	0.5	—	8.5	—	11.3	—

The egg

Eggs are laid on the under side of the leaf, often along the midrib or a vein. The female moth lives from 5 to 10 days and egg laying is heaviest during the first three days. It dies approximately a day after the oviposition period is completed.

Eggs are deposited both singly and in batches or clusters, field counts showing a range from I to 6 clusters with an average of four. When moths confined in screen cages, they deposited an average of approximately 2-6 eggs per cluster. The largest number in a single cluster under screened cage conditions in the laboratory was 8.

TABLE II

Number of eggs laid (one female in each cage).

Shebin El-Kom, 1953			Kobbeh, 1956		
Cage number	Date	Eggs	Cage number	Date	Eggs
1	March, 15th	52	11	March. 25th.	84
2	March, 15th	261	12	March, 25th	159
3	March, 15th	131	13	April, 4th.	267
4	April, 21st.	152	14	April, 4th.	286
5	April, 21st.	236	15	May, 12th	354
6	May, 19th.	383	16	May, 12th.	269
7	May, 19th.	352	17	June, 8th.	291
8	June, 21st.	231	18	August, 4th.	151
9	June, 21st.	94	19	August, 4th.	344
10	July, 29th	64	20	August, 4th.	169

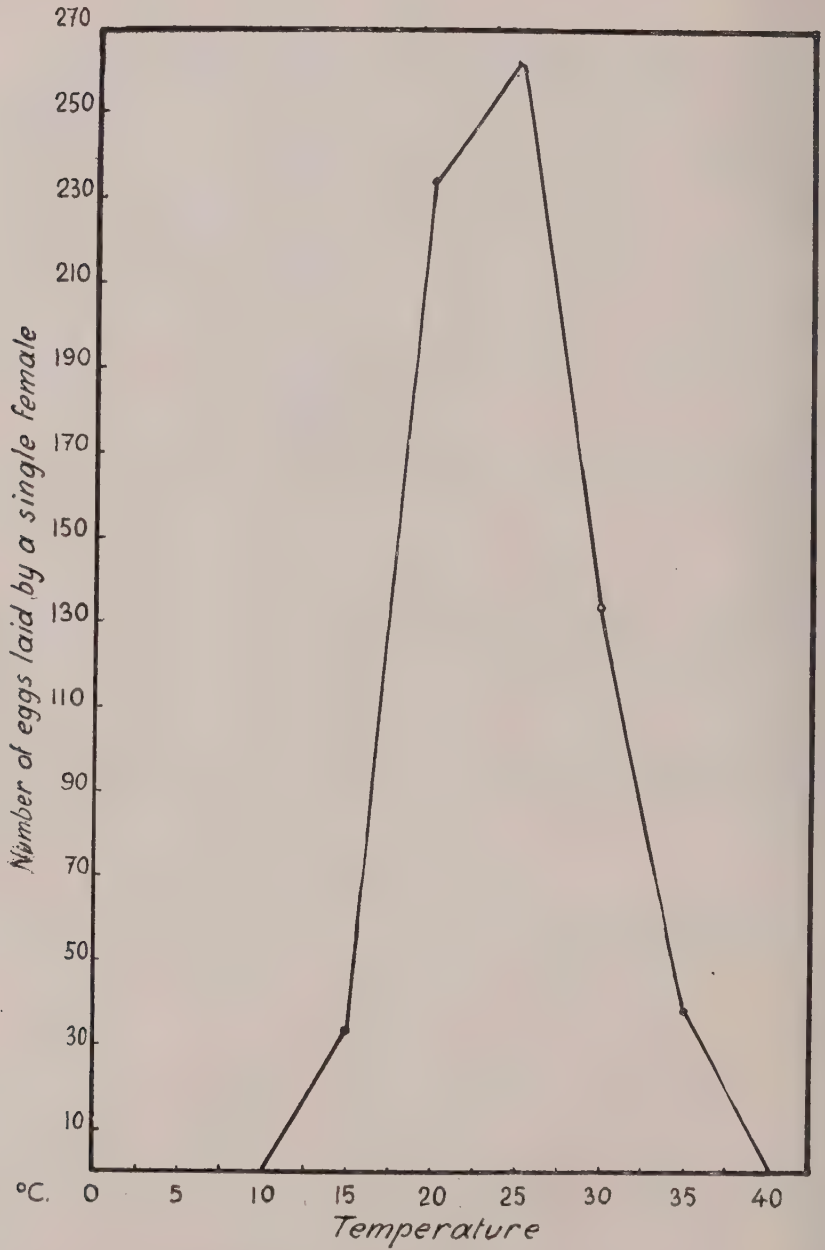

FIG. 1 : Effect of temperature on oviposition.

The rate of egg deposition is usually greatest during first and second days of oviposition. Each succeeding day, the number of eggs and eggs per cluster became less until the end of the fifth day when oviposition practically ceases.

The number of eggs laid by one female under field conditions placed in screen field cage ranged from 92 to 364. Females confined singly in small screen cages in the laboratory had an egg deposition range from 52 to 386 eggs each. The data from labratory breeding cages are shown in Table II.

Investigations on the oviposition under different temperatures were carried as follows.

Male and female, after feeding and mating, were introduced into glass cylinder cages fitted with a muslin cover top. Inside the cage a turnip leaf stood with its stalk in a water jar, and food was supplied by means of cotton wool soaked in honey water. Every day the eggs laid on the leaf were counted and the leaf was changed for a fresh one. Six cages were used for each experiment and each contained a mated pair of moths. The varying temperature of the environmental conditions were obtained by a thermostatically controlled cabinet. The results obtained are given in Table III three and in Figure 1.

TABLE III

Oviposition at different temperatures and 70% relative humidity during 1956

Temperature in °C.	Average number of eggs per female	Number of eggs laid by a single female		Average length of egg laying period
		Minimum	Maximum	
10	0	0	0	0.0
15	35	16	43	14.0
20	224	74	269	11.0
25	252	93	312	6.5
30	134	81	241	5.0
35	38	14	52	2.9

It is shown in these observations that the number of eggs deposited rises with the ncrease in the temperature until an optimum in 25°C after which it diminishes until a lethal point near 40°C.

Incubation period

The incubations period is largely dependant upon prevailing temperature conditions. Humidity apparently plays a very small role, as eggs of the same age kept in a dry place hatch in the same time as do those kept in a moist place.

In the summer, when warm weather is more or less continuous, the eggs hatch in the laboratory and out of doors in 3 to 5 days, where as early in the spring, the first eggs deposited hatched after 10 or more days Late in the autumn and winter

when cool weather is almost continuous, the incubation period may be 15 days or longer. Under constant temperature conditions in the laboratory, when temperature conditions averages 27-30°C., eggs hatch in three days

Observations were made during 1956 on the duration of egg stage and the effect of the temperature on the incubation period. Hundred of freshly laid eggs were stuck on small round glazed cardboard and were placed in thermostatically controlled cabinet at the desired temperature and suitable relative humidity. The developmental period and mortality of eggs at varying temperatures are given in Table IV.

TABLE IV

Developmental period and mortality of eggs at varying temperatures.

Temperature in °C.	Duration of egg stages in days	Mortality percentage
10	14	75
15	8	5
20	5.5	2
25	3.5	1
30	2.5	1
35	1.5	95
40	—	100

It is seen from Table IV that a temperature of 25-30°C. appears to be favourable for development and that hot weather results in death and high mortality among eggs. At a temperature of 35°C., 93% of eggs did not hatch, and at 40°C all the eggs failed to hatch.

The larva

Five larval instars are observed. Each molt is proceeded by a pre-molting period the length of which depends upon the temperature.

The newly hatched larva immediately seeks for food; even though small, it is active and can crawl a considerable distance in a short time. All larval instars are pale greenish in colour with fine erect black hairs over the body. Their length and longevity depends primarly upon temperature conditions. During the warmer months, larvae are very active and feed voraciously, causing damage to the leaves. They grow rapidly and consequently have shorter instars and reach maturity sooner than the larvae living in autumn. Table V shows the longevity of larval instars during two different seasons. It can be noted from Table V, that the average larval longevity in series A during April and May, based on 50 individual, was 261.3 hours or 10.4 days in series B, the average larval longevity based on 35 individuals being 712.5 hours or 29.7 days. The minimum number of days required for any larva to reach maturity as given in series A was 192 hours or 8 days, and the maximum

was 360 hours or 15 days, while in series B the minimum was 408 hours or about 17.9 days, and the maximum 1060 hours or about 44.2 days. Table V also shows that the average larval longevity of the second instar is invariably shorter than all the other instars. The fifth instar is of the longest duration. The length of the last instar proceeding pupation is somewhat increased by the fact that it is before the pre-pupal stage.

TABLE V

The length of larval instars during different seasons.

Instar	Series A : Observations during April and May				Series B : Observations during October and November			
	Number of individuals	Length of instar in hours			Number of individuals	Length of instars in hours		
		Extremes		Average		Extremes		Average
		Minimum	Maximum			Minimum	Maximum	
First	50	48	72	62.3	35	72	96	84.2
Second	50	24	60	35.6	35	48	72	54.8
Third	50	24	60	42.5	35	48	72	59.2
Fourth	50	48	72	46.9	35	120	252	194.3
Fifth	50	48	96	72.0	35	120	558	320.0
Total		192	360	261.3		408	1060	712.5

Pupal Stage

The larvae pupate on the food plant under a silken coccon. The duration of the pupal stage was studied during different months of the year as shown in Table VI.

TABLE VI

Duration of the pupal stage

Date of pupation	Number emerged	Date of emergence	Pupal stage	Average mean temperature in °C.
7 April, 1954	9	16 April	9	19.2
3 April, 1956	12	13 April	10	16.4
3 May, 1954	10	10 May.....	7	24.1
6 May, 1956	8	14 May	8	22.5
5 June, 1954	14	11 June.....	6	26.3
6 July, 1954	12	11 July	5	27.9
9 September, 1953 ...	8	16 September	7	24.2
8 November, 1953 ...	9	18 November	10	16.8

The pupae are considerably influenced by temperature. Various investigations were made under various constant temperature. The duration of the pupal period was found to decrease with rise of temperature. The results of these observations are shown in Table VII.

TABLE VII

Pupal period under various temperatures

Temperature in °C.	Relative humidity	Number of observations	Pupal average in days
15	70	32	14
20	70	50	11
25	70	40	7
30	70	40	5

ACTIVITY AND POPULATION DENSITY

Investigations to obtain a measure of the number of insects, the date of appearance of moths and the relative length and size of broods, were carried at Shebin El-Kom by light traps as described by HASSANEIN (1956). Two light traps were used during 1952 and four during 1953. The results of the two years trapping

TABLE VIII

Catches in light traps during 1952 and 1953

Month	1952			1953					
	Traps 1 and 2			Traps 1 and 2			Traps 3 and 4		
	Total catch	Female	Male	Total catch	Female	Male	Total catch	Female	Male
Jan. ...	0	0	0	6	1	5	17	3	14
Feb. ...	0	0	0	39	14	25	31	9	22
Mar. ...	99	58	41	60	24	36	28	12	16
April ...	416	206	210	235	99	136	224	91	133
May ...	101	57	44	25	10	15	22	4	18
June ...	21	14	7	0	0	0	0	0	0
July ...	450	190	260	1	0	1	0	0	0
Aug. ...	200	81	119	0	0	0	5	2	3
Sept. ...	48	17	31	0	0	0	16	8	8
Oct. ...	10	4	6	17	4	13	27	7	20
Nov. ...	0	0	0	1	1	0	13	5	8
Dec. ...	0	0	0	5	2	3	9	3	6
Total .	1345	625	720	389	155	234	392	144	248

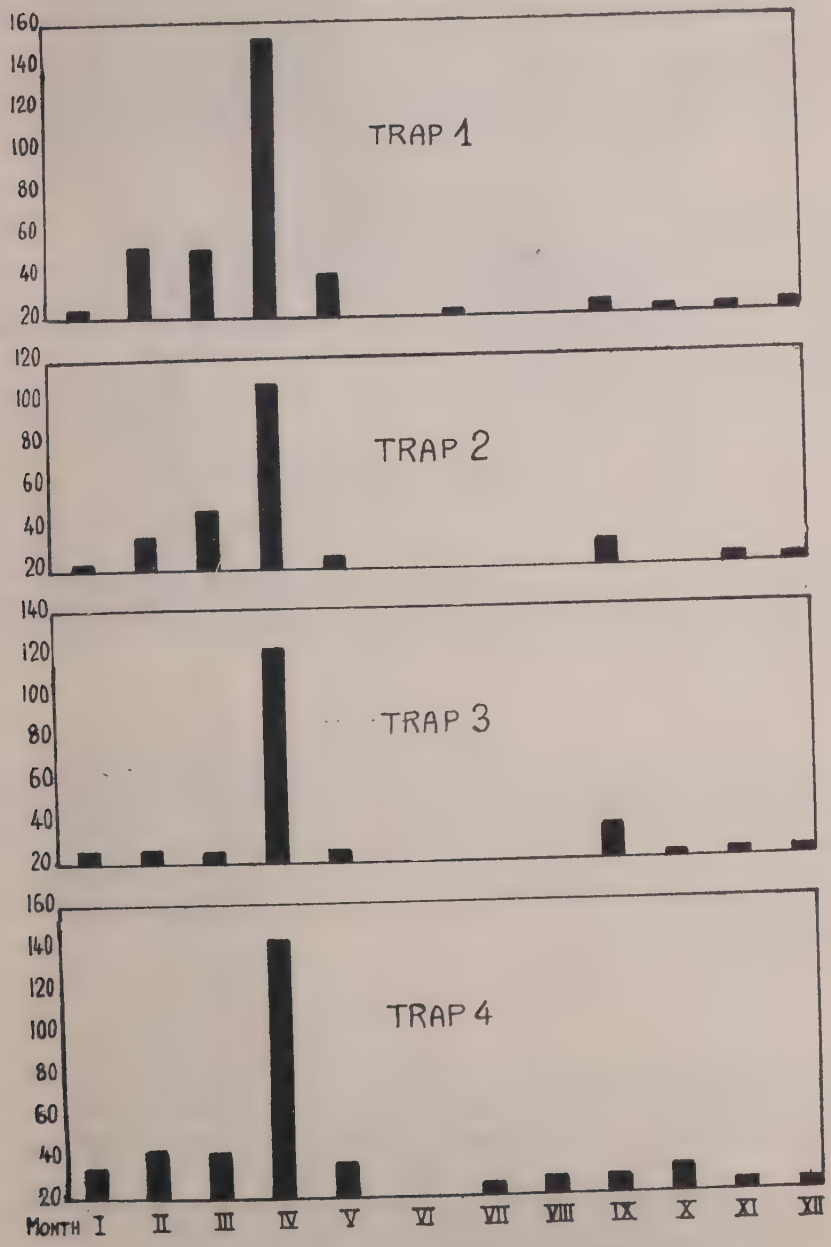

FIG. 2 : Nuuber of moths caught in traps during 1953.

are given in Table VIII and in Figure 2. Observations have shown that the moths are abundant during the spring and early summer. The peak of the catch was during April.

The first date of appearance occured on March 8th., 1952, and on January 21st., 1953. Figure 3 shows that the species has four distinct broods during 1953. The first brood was during the last week of January, February and March. The

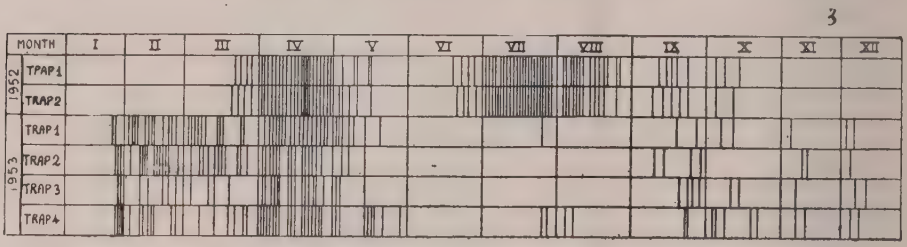

FIG. 3 : Dates of occurence of the moths in light traps in each of the two years 1952 and 1953.

second brood was during April and May. The third brood was during July and August. The fourth brood was during the fall season of the autumn. In winter the species may hibernate as an adult or as a pupa.

Proportion of sexes

In the year 1952, the number of attracted moths reached 1345, of which 720 males and 625 females (46.5%). During 1953, the catch was 782 of which 483 males and 299 females (38%). The proportion of the females attracted to the traps during the two years trapping was 43.4%. The percentage of females reared from pupae collected by random from the fields and reared singly was 43.3% during March and 45.5% during April.

PARASITISM

In 1954, 312 rearly full grown larvae were collected from the fields and reared singly during different months of the year. From these, 205 moths emerged 93 were parasitised, 5 died through *Botrytis* sp. disease and 9 died without apparent cause.

Amongst the natural parasites emerged 38 belonged to *Microplitis plutellae*, 27 to *Apanteles* sp. and 14 to *Meteorus* sp.

From 156 pupae collected during March and April of the same year and reared singly, (13.465%) of these 21 were parasitised by *Brachymeria* sp.

The Parasites

Microplitis plutellae

This braconid wasp can be considered as an important factor of the natural control of the pest. The number of parasitic grubs which emerged from a single larva ranged from 4 to 6. The coccons of the parasite are pale reddish in colour.

Apanteles sp.

The number of larvae of this Braconid issuing from each larval host varies considerably. The grubs emerged from the fourth and fifth instars ranged from go to 12 parasites, and their white cocoons were spinned on the day of issuance from the host.

Meteorus sp.

One to nine individuals of this Braconid wasp emerged from parasitized larvae.

Brachymeria femorata Panz.

Out of 256 pupae collected from the field and reared singly in jars, 27 were found to the parasitized with *Brachymeria femorata* Panz. The accounts of this parasite were described by FAURE (1926) and by KAMAL (1937 (1938) who gave a very good coloured illustration of this Chalcid in Plate I.

SUMMARY

The diamond back moth is a seasonal pest, destructive to cruciferous vegetables in Egypt. Investigations were carried out to study the biology, population density and natural enemies of the pest. The work was conducted at Shebin El-Kom during 1952, 1953 and 1954 and completed at Kobbeh (Cairo) during 1956.

Emergence of the adults takes place during the early evenings. The pre-eviposition period ranges from 1.2 days during June to 2.4 during April. The duration of the oviposition period ranges from 4.1 days in July to 6.5 days in April. The average longevity of the mated males ranges from 5.7-10.4 days and the average longevity of the mated males ranges from 6.3-15.4 days. These observations were carried out from April to October 1953 and 1954.

The number of eggs laid by one female under field conditions ranged from 92 to 364. Females confined singly in small screen cages in the laboratory deposited from 52 to 386 eggs. Eggs deposited rise in number with the increase in temperature until 25°C., after which it reduce until lethal point around 40°C.

The incubation period appears to be largely affected by the temperature. Temperature of 25-30°C. appears to be favourable for egg development and hot weather results in death and high mortality among eggs. At 35°C, 93% of eggs did not hatch and at 40°C. eclosion did not take place.

There are five instars which the larva passes and their length of life differ with the season. Fifty larvae were reared during April and May and it was found that the minimum days for reaching maturity was 8 and the maximum 15, with an averageve of 10.4 days. Thirty five larvae were used during October and November and it was found that the minimum time for reaching maturity was 17.9 days and the maximum 44.2 with an average of 29.7 days.

The duration of the pupal stages were studied during different months of the year and it was shown that the pupal stage is influenced by temperature. The pupal period ranged from 5 to 10 days. The pupal period under constant temperature from 15 to 30°C. ranges from 5 to 14 days.

The activity, population density and phenology of the moth were studied by using light traps. The investigations show that the moths are abundant during the spring. The peak of the activity is attained in April. Observations on the broods of the pest show that the insect has four distinct brood during the year 46.5% of the moths, attracted to the traps in 1952 and 38% attracted during 1953 were females, and the percentage of females in the two years was 43.4.

The percentage of females reared from pupae collected by random from the fields and reared singly during 1954 was 43.3 in March and 45.5 during April.

Three Braconid Wasps, *Microplitis plutellae*, *Apanteles* sp. and *Meteorus* sp. were reared from parasitized larvae collected from the field by random, and 27 pupae out of 256 were parasitized by *Brachymeria femorata* Panz.

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THE DISTRIBUTION OF BLOOD, WATER, AND SUGAR SOLUTIONS IN THE MID-GUT AND OESOPHAGEAL DIVERTICULUM OF FEMALE *CULICOIDES NUBECULOSUS* MEIGEN

[*Diptera* : *Ceratopogonidae*]

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INTRODUCTION

The alimentary tract of female *Culicoides nubeculosus* was described in a previous paper (MEGAHED, 1956 b). The present work deals with the distribution of the ingested blood, water, and sugar solutions in the mid-gut and oesophageal diverticulum, and elucidates the function of the diverticulum. It also attempts to relate this study to previous studies on other blood-sucking flies.

The females used were reared in the laboratory (see MEGAHED, 1956 a). They were collected at daily intervals and thus were between 0-24 hours old. They were fed as follows : blood was taken in the normal way by allowing the female to bite; water and cane-sugar solutions were given on wet cotton-wool in glass tubes.

CONDITION OF THE MID-GUT AND DIVERTICULUM IN YOUNG UNFED FEMALES

Young females collected daily from the rearing cages, had no opportunity to feed other than on water in and about the pots from which they emerged. A series of 25 dissections of such females was made to investigate the condition of the mid-gut and diverticulum. All of them had the mid-gut empty and crumpled; 17 had the diverticulum empty and crumpled; 7 had the diverticulum distended with an amber-coloured fluid; and 1 had the diverticulum distended with a colourless

fluid. However, the proportion of cases in which the diverticulum was distended was here higher than was found in many unrecorded dissections of similar females.

It has been claimed that in *Simulium damnosum* (WANSON and LEBIED, 1948) and *Tabanus* sp. (CRAGG, 1920) the diverticulum may be distended with saliva or gastric secretions. It does not seem likely in the present observations that the fluids found in some of the diverticula could be saliva or gastric secretions: serial sections and also the experiments recorded below do not favour the idea that the diverticulum of female *C. nubeculosus* acts as a reservoir for secretions. It is more likely that the fluid found was water, either drainage water (amber-coloured) from around the pots, or relatively clear water from the walls of the pots. However, the possibility could not be excluded that these fluids were indeed secretory in nature.

In an attempt to elucidate this point, adults were reared from pupae isolated in tubes and supplied only with water coloured with eosin. The tubes were inspected daily, and emerged females were removed for immediate dissection. Of the 26 females so reared, none showed the least trace of colour in either the mid-gut or the diverticulum. In every case the diverticulum was empty and crumpled.

If the amber-coloured and colourless fluids originally observed in some diverticula were indeed secretions, then there is no apparent reason why they should not have occurred in some specimens in this experiment. The fact that no fluid was found suggests that in the original observations the fluid was water and that in this experiment the eosin made the water unpalatable.

Why only some few young females should have fluid in the diverticulum is a question which is unresolved. It is likely, however, that although they are all during their first day of adult life, those with water in the diverticulum are the oldest ones.

A. Destination of blood

The majority of the females feed during the second and the third days after emergence, though a proportion may feed during the first day after emergence. The emerging females, therefore, were kept until they required a blood meal, in a collecting-cage, which contained some raisins and several petri dishes with a layer of wet cotton-wool covered by filter paper, to serve as a supply of water and to maintain a relative humidity of 80-90 per cent. They were then collected individually by means of a sucking tube, and each female was left to feed on the writer's arm to satiety. Immediately after finishing its meal the engorged female was etherized and dissected.

Out of 25 females thus treated, all had the stomach full of blood; 23 of them had the diverticulum distended with fluid (water and/or raisin sap); and 2 had the diverticulum empty and crumpled.

Though 2 of these females had the diverticulum empty and crumpled without the least trace of blood in it, it was thought possible that the absence of blood from the diverticulum in all, or at least some of the rest, was due to its being distended

with liquid. So, 10 females, after being collected from the rearing-cages, were kept for one or more days in vials at a relative humidity of 80 per cent. and were not provided with water or raisins. These females were fed individually to repletion and dissected immediately afterwards. All of them had the stomach full of blood and the diverticulum empty and crumpled without any trace of blood in it. (This also shows that the diverticulum is not a store of saliva or gastric secretions. It is hardly likely, of course, that the diverticulum was emptied during the blood meal: in the previous experiment 23 females had the diverticulum distended with liquid).

In addition to the above results, it occurred that one of the females destined to egg-laying in routine culture work fed for no less than half an hour, and became so extraordinarily engorged that it could not move freely. By dissecting it at once, the diverticulum was found empty and crumpled without the least trace of blood in it. In serial sections of flies fixed at different times after full and interrupted meals, the diverticulum was never found to contain blood corpuscles.

These results indicate definitely that blood does not enter the diverticulum, and that the diverticulum does not function as a reservoir for blood. The destination of blood is the stomach (the excess of blood is to be found in the anterior segment of the mid-gut). It is also clear that the distention of the diverticulum with fluid does not interfere with the size of the blood meal.

Observations on blood-feeding females

It has been observed that some females bite immediately they come into contact with the skin (I conclude that they are blood thirsty). Some females roam about first (I conclude that they are not, or less thirsty). The female tries to puncture the skin at the chosen site; this being achieved, the proboscis is thrust into the wound. The proboscis (except for the labium, of course), is sometimes wholly buried in the skin; at other times it is buried to from one-third to one-half of its length. It appears that the difference in the degree of insertion of the proboscis is due to the difference in the availability of the blood in the different sites, i.e., it depends upon the vascularity of the point of attack.

According to LUTZ (1912), in consequence of the shortness of the lancet in the blood-sucking ceratopogonids this must be buried deep in the skin close up to the head. STEWARD (1933) states that *C. nubeculosus* thrusts its proboscis till "it was buried up to the base of the antennae". This statement is an exaggeration as it means that the part of the head from the base of the proboscis to the base of the antennae, and also the labium, are thrust through the skin. My own observations, in agreement with the findings of GAD (1951) and JOBLING (1928), make it clear that this is not the case.

It was noticed that a small number of females, especially during the first day, try unsuccessfully to obtain a blood meal. They succeed, however, in inserting the proboscis and remain with it inserted for a considerable time, then withdraw suddenly and insert it again in another spot and so on for several times; the itch

of every "bite" is usually felt, and wheals may be produced. When these females were dissected directly, no trace of blood could be detected in the alimentary tract. HILL (1947) observed the same phenomenon in *C. impunctatus* and *C. obsoletus*. LUTZ (1912) states that the first attempt of Brazilian blood-sucking ceratopogonids to insert the proboscis does not always succeed, and that the process is more or less slow, but the quantity of blood taken relative to the size of the insect is large. A similar phenomenon has been observed in mosquitoes; MARSHALL and STALEY (1932) state that a mosquito may penetrate the skin at as many as eight different points, producing that number of wheals, but not drawing blood.

When the meal is finished, if the proboscis is buried deep in the skin the engorged fly withdraws by pulling suddenly and vigorously, this being aided by the bracing action of the legs. If, on the other hand, the proboscis is inserted relatively superficially it is withdrawn comparatively freely. HILL (1947) dealing with *C. impunctatus*, states that the majority of the flies appeared to have difficulty in withdrawing their proboscis after a meal. *C. impunctatus* is a notorious man-biter, and HILL's statement suggests that this species is not well adapted to its mode of feeding. STEWARD (1933) also mentions that in *C. nubeculosus* occasionally the withdrawal appeared difficult to the fly "which seemed to press down with its feet and to pull its head back vigorously in an endeavour to extricate the proboscis".

In my observations on *C. nubeculosus* the sudden and vigorous pulling of the head, when the proboscis is inserted deep in the skin, gives the impression of reasonable effort, not of difficulty. The piercing stylets in *Culicoides* spp. are toothed (GAD, 1951; SNODGRASS, 1943; JOBLING, 1928), so when they are inserted deep in the skin it is reasonable that some effort is needed to pull them them out.

According to GAD (*l.c.*), the whole process of feeding takes from 3-4 minutes in *C. obsoletus* and *C. chiopterus*. HILL (*l.c.*) recorded that the time taken for individuals to become fully engorged varied from 3-20 minutes in *C. impunctatus* and up to 40 minutes in *C. obsoletus*. STEWARD (*l.c.*) found that the time of engorgement in *C. nubeculosus* varied from 3-8 minutes. In the present work the time of engorgement in *C. nubeculosus*, apart from individual variation, was found to vary considerably according to the condition of the females. In females which had access to water and raisin before having the blood meal, it varied from 1 min. 45 sec. to 9. min. 40 sec. (mean 3 min. 59 sec.). In females which had no access to these materials before the blood meal, it varied from 3 min. 55 sec. to 22 min. 35 sec. (mean 8 min. 37 sec.) (Table I).

From this considerable variation between the two groups, it seems that the complete fasting of the females before having the blood meal either impairs their power of sucking, or leaves the stomach so crumpled that it needs a longer time for distension. There was, however, no apparent difference in the distension of the abdomen in the females of both groups.

A few seconds after the start of the blood meal, the fly dejects drops of a clear colourless fluid which accumulate on the skin near the tip of the fly's abdomen,

or may be shot several millimetres away. The discharge of this fluid continues for some time after the finishing of the meal. Occasionally, it was noticed that some of the drops were retained at the tip of the abdomen in the form of a bubble, being protruded and withdrawn several times before being discharged. This observation may suggest that air may enter the gut during or directly after the finishing of the blood meal and is eliminated *via* the anus. It is extremely rare to detect air-bubbles

TABLE I

The time taken for the engorgement of the females.

Condition of the females	Number of females	Time in minutes and seconds
Had access to water and raisin before the blood meal; the diverticulum almost always distended with fluid.	25	1 45 1 58 2 17 2 28 2 30 2 35 2 40 2 42 2 47 2 52 2 55 3 01 3 02 3 14 3 20 3 40 3 41 3 54 4 23 4 33 4 58 7 02 7 21 8 20 9 40 (mean 3 min. 59 sec.)
Had no access to water or raisin before the blood meal; the diverticulum always empty and crumpled.	10	3 55 3 58 5 20 6 20 6 34 6 54 7 50 9 25 13 20 22 35 (mean 8 min. 37 sec).

t calculated = 3.578**
t_{33} 5% = 2.042 **Conclusion:** the difference is significant at 1% level.
t_{33} 1% = 2.750

in the diverticulum or the mid-gut. In very occasional specimens (non-blood-fed), however, a few big air-bubbles were seen in the distended diverticulum, or in the stomach, or in both. The common absence of air-bubbles from the diverticulum of female *C. nubeculosus* is in accord with what is found in *Phlebotomus papatasii* (ADLER and THEODOR, 1926), but differs from what is found in the mosquito (NUTTAL and SHIPLEY, 1903; MACGREGOR, 1930; MARSHALL and STALEY, 1932; PAWAN, 1937), and the tsetse fly (LESTER and LLOYD, 1928).

According to WIGGLESWORTH (1931 b), the discharge of much clear fluid soon after feeding is characteristic of nearly all blood-sucking insects, and there has been much speculation as to its nature : it has often been regarded as "serum" separated in the intestine from the blood corpuscles, while in *Glossina*, LESTER and LLOYD (1928) found that it is produced by the Malpighian tubules. WIGGLESWORTH (*l.c.*) dealing with *Rhodnius prolixus*, states that it is a salt solution, more or less isotonic with the ingested blood, which serves for the rapid elimination of the

unwanted salts in the diet; he also thinks that this is probably true of other blood-sucking insects. According to him, about 75 per cent. of the water in the meal is got rid of in this way, and he states that it can be shown by calculation that this volume of isotonic salt solution will contain nearly all the salts in the blood.

STEWARD (*l.c.*) states that in *C. nubeculosus* this fluid sometimes appeared to be tinged with blood either from the previous meal of blood, or from one end of the alimentary tract to the other, during the meal which was being observed. I have never observed this phenomenon though I have fed hundreds of females on my arms. In one case, however, a female took a second blood meal some days after the first meal, and during feeding it dejected some brown viscous drops which were undoubtedly faeces. This was an abnormal case, and this female died the next day. The suggestion of STEWARD that the fluid might have been tinged with blood from the previous meal does not seem probable. The females of *C. nubeculosus* normally take only one full blood meal in every gonotrophic cycle, and usually lay their eggs 3-4 days afterwards, by which time there is no trace of blood in the alimentary tract.

While feeding, the females of *C. nubeculosus* are not easily disturbed. If the tube is removed while the female is engaged in its meal, the insect remains feeding: neither shaking the hand, nor scratching the skin, nor blowing smoothly on the fly, nor even blowing some whiffs of tobacco smoke, will oblige the feeding females to leave its feeding place. On the other hand, if a hot needle or a piece of filter paper wet with ether approaches the feeding female, it instantly leaves the feeding site. In its persistence the female *C. nubeculosus* differs from that of *Phlebotomus papatasii* which, according to WATERSTON (1922), is easily disturbed, the slightest movement of the skin being sufficient to put it to flight.

When the distended stomach is incised, the contained blood escapes in granular lumps (an appearance which is due to the agglomeration of the corpuscles). WIGGLESWORTH (1929) describes a similar appearance for the blood found in the anterior segment of the mid-gut in *Glossina*; as true agglutinins are absent, he states that this pseudo-agglutination is mearly the result of the absorption of fluid.

To the writer, the bites and the red spots which form around the sites of puncture are quite painless and, apart from a slight inclination to scratch the skin after feeding a lot of females, never caused any disagreeable sensations. GAD (1951) mentioned that he was not affected by the bites of *C. obsoletus* and *C. chiopterus*, while JOBLING (1928) described the intense irritation caused to him by the bites of *C. obsoletus* and *C. vexans*, though to him the irritation and swelling caused by the bite of *C. pulicaris* was of a very short duration. Actually, as stated by Gad, this confirms the general conception that some people are more susceptible subjects to the bites of midges (or mosquitoes).

B. Destination of water and sugar solutions

The females used in this study were given water and cane-sugar solutions stained with eosin for easy detection. Two concentrations of the sugar solution

were used. The first was approximately 66.6 grams of sugar per 100 c.c. of solution, and is here termed "concentrated solution". The second was approximately 4.18 grams of sugar per 100 c.c. of solution, and is here termed "dilute solution".

Some females were allowed to feed individually on the stained liquid for a minimum time so as to take only as much as might be easily detected, and thus show which part of the gut first receives it. For this purpose nearly a half minute was found satisfactory. The fly was then removed, etherized at once and dissected. Others were left to imbibe the liquid to satiety.

1. *Destination of water*

The process of sucking water, at least by the described method, is not continuous. The female dips its proboscis in the wet cotton-wool for a very short while, then withdraws it, rubs it several times with the fore-legs, then re-inserts it in the same, or another, place. Because of this discontinuity of sucking, each female was allowed to dip its proboscis for serveral times within the time limit of half a minute.

During the first day of adult life, very few of the females could be induced to ingest the stained water; this is either an effect of the eosin, or the flies were not thirsty. When the females were introduced to the "water" tube they climbed its walls towards the light, paying no attention to the wet cotton-wool. It was necessary to shake them from the walls and to invert the tube to oblige them to cling to the cotton-wool. Although they appeared to be sucking it was found by dissecting them that the great majority of them did not ingest the stained water. Out of 13 females dissected after such trials, only 3 females were found to have ingested the stained water, which was seen in the mid-gut; the diverticulum was empty and crumpled in 1 female, distended with plain water in the second, and distended with dirty water in the third. Why these last two females with distended diverticulum ingested the stained water, while others with crumpled diverticulum did not ingest it is not understood. The other 10 females had the gut empty and the diverticulum empty and crumpled. The low number of females which ingested the stained water seems to conform with my general impression concerning the occurrence of females of less than 24 hours old which had the diverticulum distended with plain or dirty water.

By starving the collected females for one day at a relative humidity of 80%, and then introducing them individually to the "water" tube, almost all of them ingested the stained water readily (contrary to the females used in the previous experiment, and those reared from isolated pupae supplied with stained water, all of which were females in the first day of adult life). Out of 9 females thus treated, 8 females ingested the stained water, and 1 female did not: the female which did not ingest the stained water had the midgut empty and the diverticulum empty and crumpled. Out of the 8 females which ingested the stained water, 4 had the diverticulum empty and crumpled, 3 had a trace of the stained water in the diverticulum, and 1 had the diverticulum half-distended with it: in all of them the stained water was seen in the mid-gut.

When 3 starved females were left to imbibe the stained water to satiety the result was odd. In all of them the stained water was seen in the stomach, but none of them had the diverticulum distended with it; the diverticulum either contained only a trace or none at all. This is strikingly different from what we have seen in the previous experiment in which one of the females which were left to imbibe the water for half a minute had the diverticulum half-distended with it. It is also different from what was found in some of the young females collected from the rearing-cages, and many females collected from the collecting-cage, in which the diverticulum was distended with water. It was necessary, therefore, to supply plain water instead of the stained water, as it was suspected that the stain rendered the water less palatable to the flies so that these ingested only a little of it.

Four flies were starved as usual, and each of them was given plain water by the same method, to satiety. Each fly was dissected directly after finishing the ingestion of water. It was found that the oesophageal diverticulum was much distended with the plain water in 3 flies, and little distended with it in the fourth fly; in all of them the plain water was seen in the mid-gut. This proves the lesser palatability of the stained water.

It is evident from these results that the ingested water is dispatched first to the mid-gut and, when the urgent need for water is satisfied, the excess of the ingested water is directed to the diverticulum. It is also clear that the oesophageal diverticulum serves as a reservoir for water.

2. *Destination of cane-sugar solutions*

It was observed that the females commonly ingested the stained sugar solutions more readily than the stained water; a far less number did not ingest it. Although the process of sucking the stained sugar solutions is also discontinuous, as is the case with the stained water, the fly remains sucking for a longer period before it withdraws its proboscis. The amount of the ingested solution is also greater, in the allowed time, than in the case of the stained water.

(a) The concentrated solution

Four females, after being collected from the rearing-cages, were allowed individually to imbibe the solution for about one-half-minute. Each of them was then removed, etherized at once and dissected. They were all found to have the diverticulum more or less distended with it, while the mid-gut contained at most a trace of it.

Four females starved as usual were allowed individually to imbibe the solution for the same time, then were treated as usual. They were all found to have the diverticulum more or less distended with the solution, while the mid-gut contained not a trace of it.

Each of 4 other starved flies was allowed to imbibe the solution to satiety. They were all found to have the diverticulum fully distended with the solution, while the mid-gut had at most a trace of it.

These results show that the concentrated solution is dispatched directly to the diverticulum, and that the mid-gut, during the time of ingestion, gets at most a trace of it. It is interesting, however, to note that in some unrecorded females which happened to have the diverticulum distended with water taken up from the rearing-pots, the concentrated solution was dispatched to the mid-gut, which became more or less distended with it. It is also evident that the diverticulum serves as a reservoir for the concentrated sugar solution.

(b) The dilute solution

In this experiment, all the females used were starved females. Each of 6 females was allowed to imbibe the solution for about half a minute and then dissected directly. They were all found to have the mid-gut more or less distended with the solution, while the diverticulum was empty and crumpled.

Three other females were allowed, one by one, to imbibe the solution to satiety. They were all found to have both the mid-gut and the diverticulum more or less distended with it. This result is in marked contrast to what was shown in the cases of the stained water and the stained concentrated sugar solution.

These results indicate that the dilute sugar solution is dispatched first to the mid-gut, and that when the latter has received a sufficient amount, the surplus of the ingested solution is directed to the diverticulum. It is also clear that the diverticulum serves as a reservoir for the dilute sugar solution.

DISCUSSION AND CONCLUSIONS

A. Blood

In fully gorged females of *Culicoides nubeculosus* (and also females which got an interrupted meal), which were given blood by means of a bite, the blood was always found in the mid-gut but never in the oesophageal diverticulum. When the females were allowed access to water and raisin before they took the blood meal, the diverticulum was almost always found distended with the water or raisin sap, and in a very few cases it was found empty and crumpled. If, on the other hand, they were starved before they took the blood meal, the diverticulum was always found empty and crumpled. In no case was the diverticulum found to contain even the least trace of blood. This indicates clearly that the oesophageal diverticulum in female *C. nubeculosus* does not serve as a reservoir for the ingested blood.

The absence of the ingested blood from the oesophageal diverticulum in the fully gorged (and also unreplete) females of *C. nubeculosus* is in accord with what has been found in *Simulium nigroparvum* (Cox, 1938), *S. damnosum* (Lewis, 1953; Wanson and Lebied, 1948), *Phlebotomus papatasii* (Adler and Theodor, 1926), *Tabanus* (Cragg, 1920), *Chrysops silacea* (Wigglesworth, 1931 a), and *Stomoxys calcitrans* (Kuzina, 1942), but differs from what has been found in *Haematopota*

pluvialis (CAMERON, 1934), *Glossina* (LESTER and LLOYD, 1928, and also in mosquitoes by some of the mosquito students.

In the case of mosquitoes, the results have been discrepant. NUTTALL and SHIPLEY (1903) state (that blood is also taken up into the sacs has already been stated by Grassi, and de Grandpré and Charmoy". PATTON and CRAGG (1913, p. 110) state that in mosquitoes killed during the act of feeding, the diverticula were always found to be full of blood. ROY (1927) dealing with *Anopheles subpictus* and *A. stephensi*, found that blood was never present in any sac before the stomach was full, and he states that it is the surplus quantity, therefore, that is stored in the diverticula. PHILIP (1930) states that in *Aëdes aegypti* a small portion of the blood meal seems to pass through the diverticula during feeding; however, MACGREGOR (1931) is of the opinion that "any blood or lymph obtained at the site of the first puncture which remains in the pharyngeal pump, the buccal cavity or the proboscis is deflected into the diverticula". MARSHALL and STALEY (1932) state that when mosquitoes feed on blood, all the blood goes direct into the mid-gut. They also state that traces of blood, negligible in quantity but sufficient to cause visible colouration are occasionally to be observed in the diverticula; they think that this appears more likely to happen in cases where no previous meal of raisin juice has been taken. PAWAN (1937) claims that there is a difference between *Aedes* (*Stegomyia*) *aegypti* and *Anopheles tarsimaculatus*; in *Aëdes*, immediately after a blood meal the diverticula become distended and filled with blood cells, but in *Anopheles* they are never distended, or appreciably filled, with blood immediately after a full meal and even with an engorged and distended stomach. ROY and GHOSH (1940), however, do not agree with PAWAN'S view concerning *Anopheles*. ROBINSON (1939, p. 231) mentioned that the function of the anticoagulin in the saliva of mosquitoes seems necessary "because the blood is stored in the ventral reservoir for a considerable time before it is received into the stomach for digestion". LUMSDEN (1947) states that in the majority of fed *Aëdes aegypti* mosquitoes, blood was found in the stomach alone, but partly fed flies showed higher proportion with blood in the diverticula than did those fully gorged. FISK (1950), who also worked with *Aëdes aegypti*, states that the blood passed directly to the mid-gut. TREMBLEY (1952) states that under all conditions, blood was dispatched primarily to the stomach, and with few exceptions, in small amounts to the diverticula. On the other hand, WRIGHT (1924) dealing with the British mosquitoes, states that although mosquitoes which had already fed on blood were fairly common, he never encountered any mosquito which had the least trace of blood in the oesophageal diverticula. (Nevertheless, he has given Tables which show that 2 females had much blood in the diverticula, and that 21 had traces). MACGREGOR and LEE (1929) and MACGREGOR (1930) state that blood withdrawn by puncturing the skin passes directly into the stomach and not into the diverticula. BISHOP and GILCHRIST (1946) state that blood and blood fractions pass to the stomach.

It is apparent from the reviewed literature that in the blood-sucking Diptera,

the destination of the ingested blood is the mid-gut, and that in some species it also goes to the oesophageal diverticulum (or diverticula). The presence of blood in the diverticulum (or diverticula) has been demonstrated in several species of mosquitoes (Nematocera), *Haematopota pluvialis* (Brachycera), and *Glossina* (Cyclorrhapha). In these flies it is the surplus of blood that enters the diverticulum (Roy, 1927; Cameron, 1934; Lester and Lloyd, 1928); Pawan (1937), however, claims that in *Aëdes* (*Stegomyia*) *aegypti* it is not merely the excess of the ingested blood from an over-distended stomach which passes on into the diverticula, and MacGregor (1931) thinks that it is the blood (or lymph) which remains in the pharyngeal pump, the buccal cavity or the proboscis that is deflected into the diverticula. The portion of the blood meal contained in the diverticulum, is probably never detained there very long (Patton and Cragg, 1913; Roy, 1927; Philip, 1930; Pawan, 1937). The blood found in the diverticula of unreplete mosquitoes is attributed to probable regurgitation from the stomach when feeding is interrupted before its normal completion (Philip, 1930; Marshall and Staley, 1932; Lumsden, 1947).

Various opinions have been forwarded as to explain the presence of the ingested blood in, or its absence from, the oesophageal diverticulum (or diverticula). Wright (1924), dealing with mosquitoes, follows the assumption that the original food of the Culicidae was plant juices, and that blood is an "acquired taste", and concludes that in the case of blood meals we are dealing with a recently acquired character, and consequently must not be surprised to find, as we certainly do, that these organs function irregularly. He also suggests as a provisional hypothesis that the original function of the oesophageal diverticula is that of food reservoirs, but that this function is largely suspended in the case of blood-sucking females. Trembley (1952), also dealing with mosquitoes, suggests that the proportion of mosquitoes showing blood in the diverticula appeared to be a distinguishing physiological characteristic of the species. Lester and Lloyd (1928), dealing with tsetse flies, state that when the diverticulum is destroyed by pricking, it is found that the mesentron takes up more blood at subsequent meals, and they conclude that the function of the diverticulum is therefore to allow the fly to take a full meal rapidly with little risk of rupture of the intestine. It seems likely, however, that the presence of blood in the diverticulum (or diverticula) of some species,means that the blood requirements of the species are larger than the full capacity of the mid-gut. A careful study of the size of the blood meal (or meals) necessary for egg development in each species, and the size of the fully distended mid-gut, may throw light on this problem.

B. Water and sugar solutions

When the flies were given eosin-stained water and cane-sugar solutions by means of wet cotton-wool for about half a minute each, the water and the dilute sugar solution were found to have been dispatched to the mid-gut, while the concentrated sugar solution was dispatched to the diverticulum. Nevertheless, when it happened that the diverticulum was already distended with water (taken up from

the rearing-pots) at the time of the experiment, the ingested concentrated solution was dispatched to the mid-gut.

On the other hand, when the females were allowed to imbibe the stained fluids to satiety, the stained water was found in the mid-gut, while the diverticulum contained only a trace or none at all; the dilute sugar solution was found in both the mid-gut and the diverticulum; the concentrated sugar solution was found in the diverticulum, while the mid-gut contained only a trace.

When the females were given plain water instead of the stained water, to satiety, the diverticulum was found to be distended with it. We have already seen that in some females within 24 hours old, and also in many females taken from the collecting-cage, i.e., supplied with water and raisin, the diverticulum was distended with water. Why the diverticulum did not become distended with the stained water may be attributed to some effect of the stain. As it was observed that the quantity of the ingested stained water was far less than that of the sugar solution, it is probable that the stain made the water less palatable so that the females ingested very little of it — an effect which the sugar annuls.

These results show clearly that the first destination of water and the dilute sugar solution is the mid-gut, while that of the concentrated sugar solution is the diverticulum. They also show that the oesophageal diverticulum serves as a reservoir for water and sugar solutions.

Experiments with water and sugar solutions have been performed on several blood-sucking Diptera, especially mosquitoes. Wright (1924) found that mosquitoes fed on sugar solution or fruit juice had the diverticulum full of the fluid, while the mid-gut was empty. MacGregor (1930) states that the normal destination of water, fruit saps and sugar-containing fluids taken up by the mosquito is the diverticula. Roy and Gosh (1940) state that when a mosquito is allowed to imbibe fluid from wet cotton-wool, water and sugary solutions are invariably found in the diverticula. Bishop and Gilchrist (1946), however, state that sweet solutions containing glucose or honey pass to the stomach or the diverticula but only the diverticula become distended. Fisk (1950) found that in *Aëdes aegypti* a 5% sucrose solution went to the crop but not to the stomach. Trembley (1952) states that glucose solutions, regardless of the species or manner of feeding, were found primarily but not exclusively in the diverticula. In *Simulium damnosum*, Wanson and Lebied (1948) found that the ingested sugar solutions and fruit juices passed into the crop. In *Stomoxys calcitrans*, according to Kuzina (1942), coloured sugar syrups pass directly into the crop.

We have seen that MacGregor (1930) and Roy and Ghosh (1940) state that water imbibed by mosquitoes is transported to the diverticula. This is quite different from what is found in *C. nubeculosus*, in which the imbibed water is dispatched first of all to the mid-gut. On the other hand, with the exception of Bishop and Gilchrist (1946) who found that sweet solutions containing glucose or honey pass to the stomach or the diverticula, and Trembley (1952) who found that glucose solutions may pass to the stomach, the other authors (i.e., Wright, 1924;

MacGregor, 1930; Roy and Ghosh, 1940; Fisk, 1950) state that that sugar solutions, sugary fluids, and fruit juices taken up by mosquitoes pass directly into the diverticula; this also applies to *Simulium damnosum* (Wanson and Lebied, 1948) and *Stomoxys calcitrans* (Kuzina, 1942). Roughly speaking, these results agree only with those obtained when the females of *C. nubeculosus* were fed on the concentrated sugar solution, and differ from those obtained when they were fed on the dilute sugar solution. However, as the concentration of sugar in the fluids was not given (except Fisk, 1950), the difficulty of making a thorough comparison is quite apparent. There is one thing in common, however, and that is, the oesophageal diverticulum (or diverticula) serves as a reservoir for water and sugar solutions.

Why one fluid is dispatched to the mid-gut and another to the diverticulum is an unresolved question. Fisk (1950) undertook experiments to discover some relatively simple property or properties of blood which enables it to pass directly to the mid-gut. The blood properties simulated were pH, temperature, peptone content, amino acid content, viscosity, osmotic pressure, and the particulate nature of the erythrocytes. None of these experiments, however, was successful. It is likely, as is suggested by MacGregor (1931), that a selective and voluntary control is exercised by the insects in regard both to the aspiration and destination of ingested food.

The importance of the function of the oesophageal diverticulum in the blood-sucking Diptera as a reservoir for water and sugar solutions, has been pointed out by Denisova (1943; 1949). This author has shown that the injection into the body cavity of *Anopheles maculipennis* and of Tabanids, of amounts of water greater than 50% of the body weight produces an osmotis shock; Tabanids are more susceptible than *Anopheles*. He concludes that the crop, having a water-impermeable wall, represents a valuable adaptation which controls the expenditure of the consumed water and the variation of the blood concentration. The function of the crop, therefore, enables the blood-sucking Diptera to consume hypotonic solutions, namely of water and of plant juices, notwithstanding the rapid absorption of fluids through the mid-intestine. He also quotes Biklemishev to the effect that this double nutrition is typical of all blood-sucking Diptera, and is lost only in the much specialized forms *Glossina* and Pupipara. Hocking (1953) found that the (northern) biting flies obtain the energy for flight almost exclusively from floral nectar, of which some flies may carry in their crops quantities ranging up to 217% of their basic weight.

It is noteworthy that peculiar functions have been attributed to the oesophageal diverticulum in some blood-sucking Diptera. Cragg (1920) observed a clear fluid in the crop of *Tabanus*, and he suggested that some of the secretion from the mid-gut had been regurgitated into it. But Wigglesworth (1931 a) who at first thought that the fluid in the crop of *Chrysops silacea* was saliva and that the crop served as a reservoir for saliva, suggests that it is possible that the crop contents represent free fluid obtained from the surface of plants and that as in mosquitoes, when the insect feeds on such substances the crop does function as a temporary reservoir.

Wanson and Lebied (1948) found that the fluid from the crop of *Simulium damnosum* when injected in man produced the same reactions as the insect saliva, and concluded that the crop is a reservoir for saliva. But they, and also Lewis (1953), found that the crop serves as a reservoir for sugary fluids. It seems to the present writer that the reactions produced, which were the same as those produced by the insect saliva, might have been due to bacteria or fungi (or to their products) contaminating the injected crop contents. (In serial sections of *C. nubeculosus*, fungal hyphae were sometimes seen in the oesophageal diverticulum). Another possible reason for these reactions is the saliva which probably becomes mixed with the imbibed fluids at the time of ingestion.

SUMMARY

The oesophageal diverticulum in female *C. nubeculosus* functions as a reservoir for water and sugar solutions, but not for blood.

The first destination of the ingested water and the dilute (4.18 grams per 100 c.c. of solution) cane-sugar solution is the mid-gut, and that of the concentrated (66.6 grams per 100 c.c. of solution) cane-sugar solution is the oesophageal diverticulum.

Notes on the habits of the females during feeding are presented.

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STUDIES ON THE POLYHEDROSIS-VIRUS DISEASE OF THE COTTON LEAF-WORM, *PRODENIA LITURA* F., IN EGYPT

(with 1 Text-Figure, 1 Graph, and 6 Tables)

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INTRODUCTION

In his paper on "Polyhedrosis-virus disease on cotton leaf-worm, *Prodenia litura* F.", SALAH ABUL-NASR (1956) has mentioned the attempts previously done in Egypt in view to contaminate the cotton leaf-worm with bacterial diseases. He gave also the results of his personal experiments on the subject.

As indeed very little is known on the control of the cotton leaf-worm by bacterial diseases, laboratory and field tests has been carried out by the present author as a new contribution to this very important problem.

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METHODS AND TECHNIQUE

The virus material was secured from infected *Prodenia litura* larvae collected in the fields.

To initiate infection in *Prodenia* larvae for the laboratory studies of the disease, a substantial amount of healthy larvae at the required stage of development were fed for a limited period on clover or cotton sprigs which had been sprayed with a virus suspension a short time before. They were fed thereafter on normal food and kept for observation and studies.

For mass production of the virus for field spraying tests, *Prodenia* larvae were collected from the field and bred in the laboratory. When they reached their medium size, they were fed on cotton or clover sprigs which had been treated with suspensions secured from diseased larvae. To ensure the best results, larvae were crowded in breeding cages kept under fairly humid conditions. Large numbers of the larvae showed symptoms of the polyhedrosis and the dead disintegrated bodies of such larvae were carefully collected twice a day and were held as a thick paste in glass jars in the refrigerator at about 6°C.

For preparing a stock of virus suspension, a small amount of distilled water was added to the paste of dead larvae in just enough quantity to allow for the blending of the paste by an electric blendor. To get a homogenous suspension, the material was blended for few minutes. The suspension was then strained under vacuum through two layers of organdy cloth to remove any undesired plant or insect large particles. Meanwhile, small quantities of distilled water were added in order to facilitate the straining process. The suspension was then kept in dark tightly stoppered glass bottles and held in the refrigerator until it was used.

By carefully collecting only the dead bodies of larvae that showed the unmistakable external symptoms of polyhedrosis and by keeping them in clean closed jars in the refrigerator for the eventual preparation of the virus suspension, the polyhedra were the only bodies of any significance that could be discerned by the microscopic examination of the suspension.

METHOD USED IN COUNTING THE NUMBER OF POLYHEDRAL BODIES IN THE STOCK SUSPENSION

Thompson and Steinhaus (1950) are of the opinion that"since there is undoubtedly some free virus (not included in the polyhedral bodies) in such a suspension, the use of polyhedra counts to ascertain the concentration of virus activity is probably open to error and only approximate the amount of virus present. Nevertheless, the polyhedral count is a convenient means of arriving at this approximation". Therefore, the polyhedra counts were used in the present work as an approximate method of measuring the concentration of the virus in the stock suspension. The following method was adopted to determine that concentration.

After the virus suspension is thoroughly shaken, 1 cc. of it is added to 999 ccs. of distilled water to get a diluted suspension 1/1000. By means of a micropipet an amount of 4 cc. of the diluted suspension is spread on a slide and evenly distributed to cover a 18 mm. square area. After the suspension is partially evaporated, the thin film that is formed on the slide is covered by a slip of the same dimension. Under the oil immersion lens of a light microscope all the polyhedral bodies present in the microscope field are counted. Fifty counts in fifty different fields representing all areas of the film are taken and the average number of polyhedra per field is determined.

The number of polyhedra per cc. of the stock suspension is calculated as follows :

The diameter of the microscope field used in the counts was found to be 0.16 mm. The area of that field, being circular, is 22/7 × 8/100 × 8/100 or 0.02 square mm. The area of the film being 18 mm. × 18 mm. or 324 square mm., is therefore 324/0.02 or 16.200 times the area of the microscope field. Each polyhedron in the field therefore represents 16.200 polyhedra in the film As the film represents only 0.04 cc. of the diluted suspension, each polyhedron in the microscope field represents 16.200 × 100/4 or 405.000 polyhedra in each cc. of the diluted suspension. As the concentration of the diluted suspension is 1/1000 the concentration of the stock suspension, therefore each polyhedron in the microscope field represents 405.000 × 1000 or 405 million polyhedra in the stock suspension.

For purpose of approximation each polyhedron in the field of the microscope was considered in the present work to represent 400 million polyhedra in the stock suspension.

The average number of the polyhedral bodies in the stock suspensions prepared as described above was shown to range from 1.000 to 3.000 million polyhedra per cc.

LABORATORY TESTS

These tests were undertaken with the object of studying the effect of polyhedrosis on the different instars of the coton leaf-worm under controlled laboratory conditions and gathering data and information pertaining to the relative effect of the virus on each and the time required between feeding on virus treated plants and the first appearance of symptoms of the disease, the final death of virus treated larvae and the peak of mortality among them as well as other information of biological significance.

A clover plot in the experiment field at Giza, which had been sprayed with a virus spray suspension 25 million polyhedra per cc, at a rate of one liter per "kirat" (=175 square metres), was used as the source of virus treated food.

Test No. 1

In the first series of tests four groups of 100 *Prodenia* larvae each, were confined separately in four wire cages 30 × 30 × 30 cms. Fresh clover sprigs placed in a fresh water bottle were provided daily to each group for a period of eleven days. The different treatments of the cages were as follows:

Cage No. 1. — Contained first instar larvae which were allowed to feed on treated clover.

Cage No. 2. — Contained first instar larvae which were allowed to feed on untreated clover.

Cage No. 3. — Contained third and fourth instars larvae which were allowed to feed on treated clover.

Cage No. 4. — Contained third and fourth instars larvae which were allowed to feed on untreated clover.

Cages were carefully separated so as to prevent any contamination of those that were provided with untreated clover and were placed in the laboratory at an average temperature of about 24°C The daily mortality of the larvae in each cage was recorded and the results are given in Table I.

TABLE I

The daily mortality of four groups of Prodenia *larvae (100 larvae each) fed on virus treated and untreated clover.*

Days after feeding	Number of dead larvae			
	First instar larvae		Fourth and fifth instars larvae	
	Fed on virus treated clover	Fed on untreated clover	Fed on virus treated clover	Fed on untreated clover
1	0	0	0	0
2	4	3	6	2
3	8	4	17	5
4	5	1	8	2
5	3	1	7	3
6	3	7	44	7
7	69	17	5	2
8	0	8	7	5
9	3	7	2	2
10	1	3	3	4
11	4	7	1	9
Total	100	58	100	41
% mortality	100	58	100	41

The results of this test indicate that :

1. — Polyhedrosis of the cotton leaf-worm attacks both newly hatched and medium size *Prodenia* larvae.

2. — All such larvae that had been fed on virus treated clover died, all showing the symptoms of the disease before their death. On the other hand, about 40 to 60% of the larvae that had been fed on untreated clover survived.

3. — The peak of mortality among virus treated larvae was reached on the sixth day after feeding on treated clover in the case of medium size larvae and on the seventh day in the case of newly hatched larvae.

4. — The first external symptoms of the disease started to show two days after feeding in many cases. It was noticed that these symptoms generally appear

three to four days before the host larvae finally die. One main symptom, of important economic bearing, is the high loss of appetite among the diseased larvae three to four days before death.

5. — Under laboratory conditions of about 24°C. average temperature, the period between feeding on virus treated clover and final death of larvae varied from 2 to 11 days. In most cases it varied from 6 to 7 days. In all cases, however, symptoms of the disease appeared about three days earlier.

6. — It was noticed that more than half of the mortalities among the larvae that had been fed on untreated clover was caused by polyhedrosis. Because of the elaborate precautions which were taken to prevent food contamination in the laboratory, the writer is inclined to believe that part of the untreated clover which was collected in the field was virus contaminated. This is just natural since the disease is indigenous in Egypt.

Test No. 2

In the second series of tests twelve sets of *Prodenia* larvae, 50 larvae each, were confined separately in twelve wire cages. These sets were grouped in six groups,

TABLE II

Relative effect of polyhedrosis on the different larval instars of Prodenia litura.

Days after feeding	Number of dead larvae											
	First instar larvae fed on		Second instar larvae fed on		Third instar larvae fed on		Fourth instar larvae fed on		Fifth instar larvae fed on		Sixth instar larvae fed on	
	virus treated clover	untreated clover	virus treated clover	untreated clover	virus treated clover	untreated clover	virus treated clover	untreated clover	virus treated clover	untreated clover	virus treated clover	untreated clover
1	0	0	0	0	0	0	9	3	0	0	1	0
2	1	0	8	0	0	2	21	5	4	0	6	0
3	0	5	12	2	5	1	6	1	16	0	17	4
4	14	0	0	1	4	0	5	0	13	0	14	0
5	7	0	4	1	4	1	2	3	10	0	5	2
6	9	0	10	0	8	2	4	1	0	0	7	1
7	8	0	6	0	19	0	3	0	0	0	0	1
8	6	0	10	0	3	0	0	0	0	0	0	0
9	5	0	0	0	3	0	0	0	7	2	0	2
10	0	2	0	2	2	0	0	0	0	1	0	0
Total ...	50	7	50	6	48*	6	50	13	50	3	50	10
% Mortality	100	14	100	12	96	12	100	26	100	6	100	20

* The two remaining larvae died on the 11th and 30th day, respectively.

two sets each. Each group represented one instar of the six larval instars of *Prodenia*. In each group one set of larvae was allowed to feed on untreated clover while the other was allowed to feed on treated clover. The cages were placed in the laboratory at an average temperature of 23°C. and the experiment was continued for ten days. The results are shown in Table II.

The results of the above test indicate that there seems to be little, if any, difference among the different larval instars relative to the effect of the virus against them.

Test No. 3

During the course of laboratory experiments and mass propagation of the virus, it was noticed that some of the infected larvae, especially those that had caught the disease late in the sixth stadium, did not die before pupation. It seemed that the infection of the larvae at that late stage did not prevent some of them from pupating and some of their pupae from giving emergence to moths. A test was carried out to find out the effect of the disease on such pupae and moths.

Large numbers of *Prodenia* larvae in advanced stage of development were collected in the field in Sakha and fed on virus treated clover in the laboratory as shown in Test No. 1. Most of these larvae died before pupation but the few that pupated were counted and the percentage of moth emergence among them was determined. This group of larvae was compared with a similar group which was

TABLE III

Effect of infecting Prodenia *larvae in an advanced stage of development on the mortality of their pupae.*

Source of larvae and nature of their food	Total number of pupae	Number of pupae that failed to emerge	Number of moths that emerged	Percentage of mortality among the pupae
Field at Sakha (1954). Fed on virus treated clover.....	170	100	70	59
Field at Sakha (1954). Fed on untreated clover.	410	138	272	34
Field at Sakha (1955). Fed on treated clover	119	87	32	73
Field at Sakha (1955). Fed on untreated clover.	120	40	80	33
Insectary breeding stock, Giza (1955). Fed on untreated clover.	107	39	68	36

allowed to feed on untreated plants. The experiment was repeated in 1954 and 1955. In the latter year a further comparison was made with a third similar group of larvae which had been picked from the regular laboratory breeding stock. The results of these experiments are shown in Table III.

The results of the above experiments seem to indicate that:

1. — A large percentage, ranging from 59 to 73%, of the pupae that were produced from larvae that had been fed on virus treated clover failed to give emergence to adults. On the other hand, this percentage ranged from 33 to 36% for similar pupae that had been fed on untreated food.

2. — Almost all moths that succeeded in emerging from pupae of the first group of larvae were weak and malformed (Fig. 1). Their wings showed a striking shrinkage due to their failure to expand properly. They soon die without depositing any eggs.

FIG. 1 : Weak and malformed *Prodenia litura* F. moths issued from larvae that had been infected with the virus disease late in the larval instar.

Under the circumstances, it was not possible to study whether the disease could be transmitted from one generation to the next through the contamination of the eggs. Further investigations are needed to clarify this point. It is to be noted, however, that STEINHAUS (1949) is of the opinion that adults of Lepidoptera are generally insusceptible to most polyhedral viruses. This, however, does not exclude them from being carriers of these disease agents.

FIELD TESTS

A number of field experiments were undertaken at Sakha government farm and Giza field in the years 1954 and 1955 with the object of getting some information on the effect of weathering on the virulence of the virus and of determining the possibilty of using polyhedrosis of the cotton leaf-worm as a practical means of control of that pest.

The effect of weathering on the virulence of polyhedrosis virus

A preliminary test was carried out in the field at Giza late in October 1954 to determine the effect of weathering on the virulence of the virus. A field plot was sprayed with a virus spray suspension at the same concentration and rate as stated before, 25 million polyhedra per cc. Two groups of medium sized larvae, each consisting of 8 series of 30 larvae each, were set. Starting on the day of spraying the field plot and daily thereafter for a period of six days and on the tenth day, two series, one from each group, were placed in separate cages. All series from the first group were provided with virus treated clover while all series from the second group were provided with untreated clover. The larvae in each of the sixteen series were observed for ten days for death by polyhedrosis. The average temperature in the field during the test was about 18°C., while the average temperature in the breeding room, where the larvae were kept, was about 23°C. The results of this experiment are given in Table IV.

TABLE IV

Number of Prodenia *larvae which died in a ten days period after feeding on virus treated clover picked from the treated field on different days after treatment, as compared to death rate among larvae which were fed on untreated clover.*
(Original number of larvae : 30 in each series).

Days after field treatment	Larvae that died within a period of ten days after feeding on			
	Treated clover		Untreated clover	
	Number	Percentage	Number	Percentage
0	30	100	10	33.3
1	30	100		
2	30	100	3	10
3	30	100		
4	28	93.3	7	23.3
5	25	83.3		
6	25	83.3	2	6.7
10	18	60		
			Average	18.3

The results of this experiment indicate that, under the field conditions indicated above, the virus seems to retain the virulence for a period of three days. Beginning with the fourth day, that virulence is gradually weakened. A 100% mortality was recorded in larvae that had started feeding on virus treated clover three days after treatment. The percentage dropped to 93.3, 83.3, 83.3, and 60% in larvae that had started feeding on such clover 4, 5, 6 and 10 days after treatment, respectively. Mortality in the control series varied from 6.7 to 33%, with an average of 18.3%.

Judging from the above results, one would assume that 80% kill of the cotton leaf-worm larvae could be obtained in the field after seven days of its treatment by a virus suspension at the concentrations and rates indicated.

The limited nature of the experiment, however, does not warrant such a general conclusion. More experiments are needed before any such conclusion of general nature is made.

Field spraying experiments

In these experiments, an ordinary low volume hand sprayer was used to deliver the diluted virus spray suspension at the rate of about 60 to 90 litres per feddan (4200 5/6 square metres). The stock suspension was so diluted that in the final analysis each kirat would receive the equivalent of one litre of a virus suspension of 25 million, 50 million or 100 million polyhedra per millitre. (the feddan would receive the equivalent of 5.3 gallons of either of these suspensions). Spraying was done in the afternoon so that *Prodenia* larvae, which are normally more active during night time, would have a chance to feed on the sprayed leaves before the polyhedra were affected by any direct sunlight. To appraise the value of the spray suspension treatment, larval counts were made on different dates, always early in the morning. At least one count was made before spraying and one or more after spraying. Each time five counts were taken and averaged. Each count represented the average number of larvae caught in a standard net after ten double sweepings. For fear that these sweepings might interfere with the population level of the larvae in the field, net caught larvae were put back alive into the same plot after being counted.

In 1954, three plots under clover at Sakha Government Farm were chosen for the experiment. Larval counts of net caught larvae were taken twice, just before the treatment and one week after the treatment. During that year the tests coincided with a period of extensive moth flight and egg laying. New *Prodenia* egg-masses were deposited daily on the plants in the plots and new larvae continued to hatch leading to a considerable increase in the larval populations one week after the treatment over that before the treatment. Nevertheless, significant data were taken and the result of the treatment were of interest as will be shown later on.

The three plots of the year 1954 were as follows:

In the first plot where clover was three weeks old, four test plots, about one third of a feddan each, were taken. These test plots were treated as follows:

Test plot A was sprayed with a virus spray suspension containing 25 million polyhedra per millilitre.

Test plot B was sprayed with a virus spray suspension containing 50 million dolyhedra per millilitre.

Test plot C was sprayed with a virus spray suspension containing 100 million polyhedra per millilitre.

Test plot D was untreated to be used as a check.

In the second plot where clover was seven weeks old, a test plot of one half feddan was treated with a virus spray suspension (25 million polyhedra per ml.), while another test plot of similar size was not treated and was used as a check.

In the third plot where clover was two weeks old, a test plot of one feddan was treated with a virus spray suspension (25 million polyhedra per ml.), while another test plot of similar size was left untreated and was used as a check. Clover in this plot was attacked by larvae of both *Prodenia litura* and *Laphygma exigua*. Larvae of the second pest, however, were in greater abundance.

The results of the above mentioned experiments are shown in Table V.

TABLE V

Results of field tests at Sakha Government Farm, in 1954.

Plot number	Date of spraying	Test plot number	Number of polyhedra per ml. in the virus spray suspension	Average number of polyhedra per ten double sweeps before treatment	Average number of larvae per ten double sweeps one week after treatment as percentage of that number before treatment	Remarks
1	October	A	25000000	74	167	Clover plants were 22 days old when test started.
		B	50000000		193	
		C	100000000		176	
		D	Control (untreated)		327	
2	November	A	25000000	20	65	Clover plants were 53 days old when test started.
		B	Control	22	168	
3	September	A	25000000	6 (*Prodenia*)	67	Clover plants were 15 days old when test started. *Prodenia* and *Laphygma* were present.
		A	25000000	34 (*Laphygma*)	138	
		B	Control	6 (*Prodenia*)	150	
		B	Control	34 (*Laphygma*)	147	

The year 1955 was a very bad *Prodenia* year. At Sakha Government farm clover was seriously attacked and was then repeatedly sprayed with chemicals. A clover plot, of one half feddan in size, was set aside, however, to be sprayed with virus spray suspension, while another plot was left untreated and was used as a control. The first plot was sprayed three times on September 17th, October 3rd and October 12th, 1955, with a virus spray suspension having one hundred million polyhedra per ml. Larval counts were made on the dates indicated in Table VI. The results of this experiment are summarized in Table VI and Figure 2. Clover in both the treated and the untreated plots was 15 days old when the experiment was started on September 17th, 1955.

GRAPH

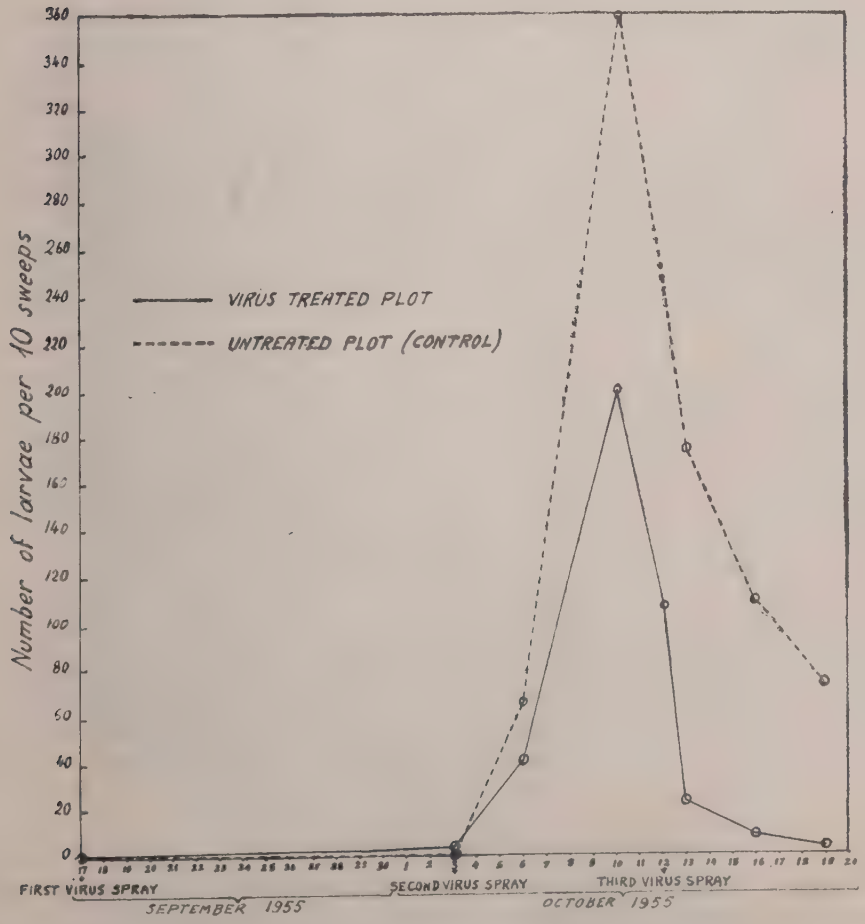

TABLE VI

Results of field tests at Sakha Government Farm (1955).
Effect of treating clover with a virus suspension (100 million polyhedra per ml.)
on the population of Prodenia litura.

Date	Average number of larvae per ten sweeps		Remarks
	Virus treated	Untreated	
September 17th-29th	1	0	First virus treatment September 17th.
October 3rd.	3	0	Second virus treatment
October 6th.	40	67	
October 10th.	198	360	
October 12th.	107	240	Third virus treatment
October 13th.	23	174	
October 16th.	8	109	
October 19th.	3	73	

Late in October 1955 at the same farm, a plot of about one feddan which was planted with clover on September 2nd of that year was found to harbor large numbers of *Prodenia* larvae in advanced stage of development. The population of these larvae in that plot just before spraying with a virus spray suspension was estimated to be, on the average, around 97 larvae per ten double sweeps. On October 25th, three quarters of that plot were sprayed with a virus spray suspension, 100 million polyhedra per ml., while the last quarter was left untreated and was used as a check. On October 30th., five days after the treatment, the field was examined. While the control gave 72 larvae per ten double sweeps, absolutely no living larvae were found in the treated plot. All larvae were dead or dying, very easily recognized hanging from the clover plants and showing all external symptoms of polyhedrosis. In this field test, the virus treatment seems to have succeeded in practically wiping out the *Prodenia* infestation. This success seems to have been achieved, however, late in the season when the temperature was already dropping down.

The results of field spraying tests carried out in 1954 and 1955 at Sakha Government Farm would seem to suggest that :

1. — Spraying clover fields with polyhedrosis virus spray suspensions though effectively reduces the population density of the cotton leaf-worm larvae in those fields, it generally does not reduce it to the economic level where the pest does not cause any appreciable damage. This is especially true when the plants are small and the degree of infestation is heavy. In such cases enough larvae do survive to cause damage to the crop.

2. — There is no significant difference in the degree of control of the pest when the virus spray suspension is used at concentrations of 25, 50, and 100 million polyhedra per millilitre.

3. — The more favorable results obtained with the virus spray suspension in the fall and early winter as compared with results obtained late in the summer emphasize the need for further research to determine whether this favorable effect is due to greater susceptibility of the larvae under fall and early winter conditions, to delecterious effect of the heat on the virus during the summer months, to both factors or to some other factors.

4. — Polyhedrosis of the cotton leaf-worm does not appreciably affect the population of *Laphygma exigua* larvae in the field under the above mentioned conditions.

SUMMARY

Some laboratory and field tests on the polyhedrosis of the cotton leaf-worm, *Prodenia litura*, were undertaken with the object of getting data and information on that virus and of determining the possibility of using it as a practical means of control of the pest. The methods and techniques employed in these studies are described.

All larval instars of the cotton leaf-worm are equally affected by the virus. Few larvae among those which are infected with the virus at the late larval instar reach the pupal stage. A good number of the pupae which are produced from such larvae fail to emerge and those which succeed in emergence produced weak malformed moths which soon die without depositing any eggs. Under laboratory conditions of an average temperature of 24 C., the period from infection to the final death of the larva is about 6 to 7 days.

Field tests carried out at Sakha and Giza Government Farms on clover in 1954 and 1955 showed that under field conditions of an average temperature of 18°C., late in October, the virus retained its virulence for three days after which that virulence was gradually weakened with a corresponding decline in the effectiveness of the virus against *Prodenia* larvae. The virus retained 80% of its effectiveness after one week and only 60% of that effectiveness after 10 days. Spraying clover fields with virus spray suspensions though effectively reduces the population density of *Prodenia* larvae, it generally does not reduce it to the economic level. There is no significant difference in the degree of control of the pest when virus spray suspensions are used at concentrations of 25, 50, and 100 million polyhedra per ml. Further studies are needed, especially with regards the effect of weather conditions on the virus in order to ascertain the reasons behind the comparatively favorable results obtained with the virus in the field in the fall and early winter.

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THE LENGTH OF THE DEVELOPMENTAL STAGES OF THE HONEYBEE WORKERS IN EGYPT

[*Hymenoptera: Apidae*]

(with 3 Tables)

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INTRODUCTION

Previous investigators have shown that the length of time required for the development of certain insects is inversely proportional to the temperatures to which these insects are exposed. In the honeybee the cycle of the activities were found to be varying in different regions in accordance with differences in climate and the sources of nectar and pollen. These factors have more or less an effect on the length of the developmental stages of the honeybee workers. With this in mind, some experiments were carried out to show the length of the developmental stages of the Egyptian honeybee workers under the enviromental conditions of Alexandria.

METHODS AND TECHNIQUE

This test was carried out in the Agricultural College apiary, University of Alexandria, on five colonies. In order to obtain eggs of definite age. A space in the middle of a hive, wide enough for three frames, was partioned off with a queen excluder at either side and at the entrance to prevent the queen from escaping in any way after the cover was placed on the hive and to allow the workers to come and go freely. A fairly strong colony of Egyptian honeybees, was transfered to this hive. and was supplied with one frame nearly full with brood about to emerge, a second empty frame, and a third frame full of honey, in this partitioned-off space. The queen was then confined in this chamber. The frames containing eggs were removed from this chamber after three hours periods of egg laying. The removed frame was

replaced by an empty one for the next series. The removed frame of eggs was then marked, dated, and kept with several other frames of brood covered with nurse bees in a super over one of the experimental colonies, with the queen confined below by a queen excluder.

The brood was then observed and every stage period was recorded until the adult workers emerged. The total number of every stage in a definite time was determined by placing a frame with cross wires, forming squares against it. Then computing the cells containing the brood against each square, multiplying this figure by the number of the squares.

RESULTS AND DISCUSSIONS

The egg

Examination off eggs took place after 66 hours from laying and every six hours thereafter untill all eggs hatched (Table 1).

TABLE I

Incubation period of workers' eggs.

Date of egg-laying	Number of frames	Number of eggs	Number of eggs hatching after:					
			66 hours		72 hours		78 hours	
			Number	%	Number	%	Number	%
5. I – 7. I.	5	250	30	12.0	150	60.0	70	28
24. I – 27. I.	4	250	30	12.0	190	76.0	30	12
10. II – 14. II	5	450	75	16.6	300	66.6	75	16.6
4. III – 7.III	4	460	95	20.7	365	79.3		
24. IV – 30. IV ...	5	1075	270	25.1	805	74.9		
16. V – 20. V	5	975	300	30.8	675	69.2		
6. VI – 12. VI ..	5	800	220	27.5	580	72.5		
3. VII – 6. VII. .	5	540	105	19.4	435	80.6		
10. VIII – 12. VIII	5	1050	315	30.0	735	70.0		
3. IX – 4 – IX	4	500	100	20.0	400	80.0		
1. X – 2 – X	4	350	75	21.4	275	78.6		
Total	51	6700	1475	22.0	5050	75.4	175	2.6

Primary observations show no eggs hatched before 66 hours. In January and February, when the temperature ranged from 53-65°F. and the workers were least active 18.8% of the eggs delayed in hatching for 78 hours, 13.5% hatched in 66 hours, and 67.5% or the majority in 72 hours. When the workers became more

active in colony duties, during the period from March to October, in a temperature ranging from 60-91°F., it was noticed that no eggs delayed in hatching for 78 hours, with an average of 25.4% hatched in 66 hours, and 74.3% hatched in 72 hours.

It is observed that the eggs that hatched in 66 hours during January — February were in the middle of the winter cluster. Those on the margins hatched later. When the winter weather got warmer (over 60°F.) the winter cluster loosened and the queen became active in egg laying outside the border of the previous winter cluster. These eggs, however, did not hatch, and died, as the temperature fell down to 53°F.

The larva

The general appearance of the larva of different age particularly with refrence to their size and position in the cell, provides criteria by which the age of the brood may be determined. This appearance is well described by NELSON and others (1924).

TABLE II

Length of periods of larval capping.

Date of hatching	Number of frames	Number of larvae	Capping after:					
			4 days		5 days		6 days	
			Number	%	Number	%	Number	%
7. I – 10. I.	5	250	175	70.0	50	20.0	25	10.0
26. I – 29. I	4	250	195	78.0	45	18.0	10	04.
12. II – 17. II	5	450	370	82.2	80	17.8		
6. III – 9. III.....	4	460	400	86.9	60	13.1		
26. IV – 30. IV ...	5	1075	925	86.1	150	13.9		
18. V – 23. V*	5	975	865	88.7	110	11.3		
8. VI – 14. VI *...	5	800	735	91.9	65	8.1		
5. VII – 8. VII ...	5	540	470	87.0	70	13.0		
12. VIII – 14. VIII*	5	1050	940	89.5	110	10.5		
5. IX – VI. IX *...	4	500	455	91.0	45	9.0		
3. X – 4. X	4	350	305	87.1	45	12.9		
Total	51	6700	5835	87.0	830	12.5	35	0.5

* Periods of the honey flows.

In the present investigation (Table II), 870% of the cells were capped over after four days, 12.5% after five days, and 5% after six days. The latter was observed to take place during January, and these were located at the outer margins of the winter cluster.

The individual differences in the time of sealing are due to the weather conditions and the stimulative effects of the honey flow. During the two honey flows

TABLE III

Total length of the developmental periods of the adult workers

Date of egg-laying	Number of frames	Number of eggs	Length of developmental periods of adult workers per days:									
			18		19		20		21		22	
			Number	%	Number	%	Number	%	Number	%	Number	%
5. I – 7. I	5	250	50	20.0	100	40.0	50	20.0	25	10.0	25	10.0
24. I – 27. I	4	250	60	24.0	125	50.0	25	10.0	20	8.0	20	8 0
10. II – 14. II	5	450	250	55.7	130	28.9	50	11.0	10	2.2	10	2.2
4. III – 7. III	4	460	300	65.2	100	21.7	50	10.9	10	2.2		
24. IV – 30. IV	5	1075	825	76.8	200	18.6	25	2.3	25	2.3		
16. V – 20. V	5	975	800	82.0	125	12.8	25	2.6	25	2.6		
6. VI – 12. VI	5	800	700	87.5	70	8.7	15	1.9	15	1.9		
3. VII – 6. VII	5	540	400	73.8	80	14.8	50	9.5	10	1.9		
10. VIII 12. VIII	5	1050	800	76.2	210	20.0	20	1.9	20	1.9		
3. IX – 4. IX	4	500	350	70.0	100	20.0	40	8.0	10	2.0		
1. X – 2. X	4	350	190	64.4	100	28.5	40	11.4	20	5.7		
Total	51	6700	4725	70.5	1340	20.0	390	5.8	190	2.8	55	0.8

(Table II), 90.3% of cells were capped over after four days. Therefore, it seems safe to conclude that the amount of incoming nectar and pollen has an appreciable effect upon the development of at least the older larvae.

Capping begins from the edges of the cells and extend gradually to the center. Meanwhile the larvae continue to be fed by the workers from a small opening in the center of the cell, until the latter are completely capped in a course of two to six hours.

The Pre-pupa

The stages after sealing until the emerging of the adults were examined after taking off the capping of only few cells, as the examined cells found to be cleaned up by the workers.

These experiments show that at the end of the fifth to the sixth day from hatching the cocoon began to be spun. This takes from 18-24 hours, until finally form a parchement like capsule completely enclosing the larva. The latter after sealing and spinning its cocoon, stayes one or two dayes quiscent, passes gradually to the prepupal stage. The skin of the larva gradually looses its shiny appearance and a clear liquid can be seen around the head and other formed parts of the pupa, which can be distinguished underneath the old larval skin.

The pupa

The pre-pupa, after eight to nine dayes from hatching, becomes slightly active and moults for the fifth time, and the young pupa emerges. The larval skin then pushed back to the base of the cell where it mixes with the yellow feceal matter, which is known as meconium.

The colour of the pupa is uniformly white at first, and then undergoes successive changes, which are well known. A few hours before the six or final moult, the full developed pupa is for the most part amber in colour.

The adult

The skin covering the pupa is shed after 18-22 days from egg-laying. the legs, wings, and mouth parts are freed. The new adult worker begins immediately to gnaw its way out, sometimes with the aid of the nurse workers.

Table III shows an average of 70.5% emerged in 18 days, 20.0% in 19 days, 5.8% in 20 days, 2.8% in 21 days, and 0.8% in 22 days.

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MACONELLICOCCUS HIRSUTUS (GREEN), A NEW GENUS, WITH REDESCRIPTION OF THE SPECIES

[*Homoptera: Pseudococcidae-Coccoidea*]

(with 1 Text-Figure)

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INTRODUCTION

This paper is mainly concerned with a pest commonly known as "the Hibiscus mealybug", whose first record in Egypt was from a private garden near Cairo in 1912. The discovery of this mealybug had been so alarming that it was reported in several Egyptian publications offering informations about its description, origin, host plants, biology, nature of damage, areas infested, legislation to localize the attack, and control measures, chemical and biological.

Through a trial to re-organize the coccid collection of the Ministry of Agriculture, Egypt, many slides labelled "*Phenacoccus hirsutus* Green" were examined. These mounts represent the Hibiscus mealybug collected between 1919 and 1948 at various localities from the Mediterranean seashore up to Upper Egypt. The specimens were from the following host plants, arranged alphabetically: *Albizzia lebbek*, *Anona* sp., *Asparagus* sp., *Chenopodium album*, *Chrysanthemum* sp., *Erythrina* sp., *Ficus elastica*, *Ficus laurifolia*, *Gossypium* sp., *Hibiscus esculentus*, *Hibiscus schizopetalus*, *Opuntia* sp., *Phaseolus vulgaris*, *Phoenix dactylifera*, *Psidium guajava*, *Punica granatum*, *Vitis vinifera*, and *Zea mays*.

The examination of this material along with other recently mounted specimens developed into the interesting nomenclatorial problem discussed below. The discussion had to be followed by the proposal of a new genus for *hirsutus* Green and by an illustrated redescription of this species.

Gratitude is here due to the University of Ein Shams as well as to the Ministry of Agriculture, Egypt, for offering all the facilities required for the present work.

DISCUSSION

In 1921, HALL reported that the insect under consideration had been thought at first to be a new species and the name *Pseudococcus hibisci*, was proposed for it; but soon he withdrew that proposal when LAING of the British Museum (Natural History) identified the material in question as *Phenacoccus hirsutus* Green. Then HALL reported that GREEN showed him some preparations of *hirsutus*, and these proved to be similar to the Egyptian material.

Meanwhile, there are in the collection at hand, three preparations labelled "*Phenacoccus hirsutus* Green", collected in 1919 by Prof. L.H. GOUGH on cotton from Pusa (India), the type locality of this species, and these are also similar to the Egyptian specimens.

Therefore, *hirsutus* is going to stand as the specific name for the material subject of this study.

The generic status of the Hibiscus mealybug represents the bulk of the problem. On examining the material, it proved to be strikingly off the line of *Phenacoccus* Cockerell. It lacks the main characteristics of this genus; i.e. without a tooth on the claw, without a preocular pair of cerarii, without quinquelocular disc pores, and without the common phenacoccine condition of the outer band of pores around the anal ring. The only thing that may suggest its relation to *Phenacoccus* is the 9-jointed looking antennae due to a pseudo-articulation in the terminal joint, a character that cannot stand alone in this genus without the other supporting and more principal phenacoccine characteristics.

On the other hand, having an anal lobe bar, and having the anal lobe apical setae longer than the anal ring setae, the material at hand could be practically introduced into the tribe *Planococcini* of Ezzat and McConnell.

In confirmation to this conclusion, Prof. MCCONNELL of the University of Maryland, had been requested to examine some of the Egyptian material in comparison to that labelled *Phenacoccus hirsutus* Green in the United States National Collection. Unfortunately, no specimens of authentic GREEN material were there, nor was there any from India. He kindly examined some Philippine material that Dr. MORRISON had identified according to GREEN's description. The Philippine specimens are also far of *Phenacoccus* and generally similar to *Planococcini*.

This being the case, the Hibiscus mealybug is here redescribed under *Maconellicoccus**, a new genus in the tribe *Planococcini*.

(*) This genus is named after Prof. H.S. MCCONNELL of the Department of Entomology, University of Maryland, U.S.A., as a sign of regard to his successful efforts in coccid taxonomy.

In the illustration that accompany the redescription of the species, the central drawing represents the adult female with the left half showing the dorsal surface and the right half showing the ventral surface ($\times 20$); for better demonstration, the disc pores in this central figure are drawn about twice as large as they should be.

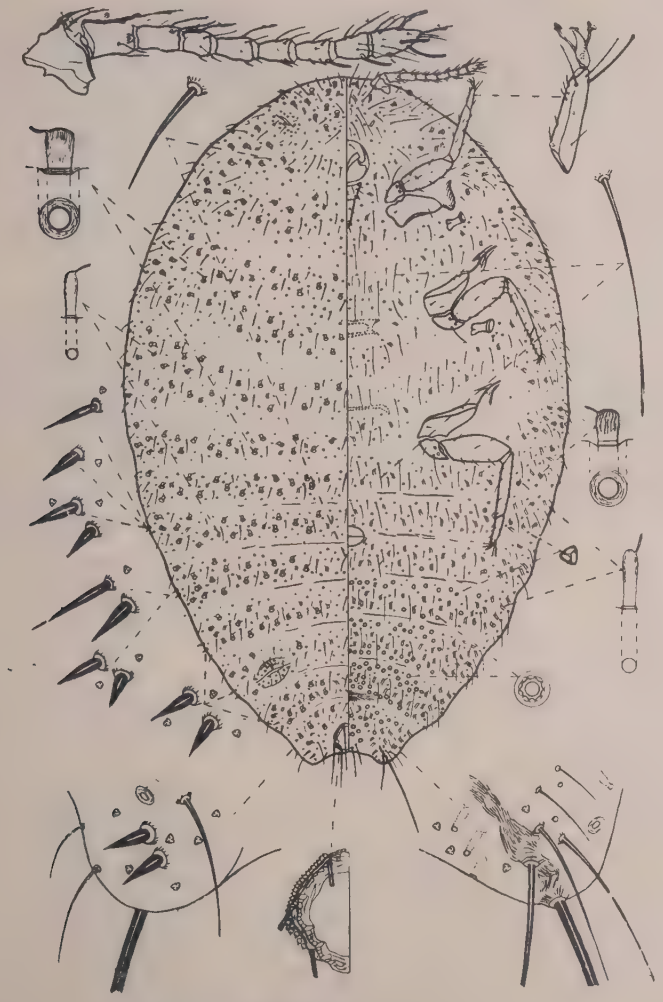

FIG. 1: *Maconellicoccus hirsutus* (Green).

Around the over-all drawing, certain body parts and dermal structures are drawn to a much larger scale in order to clarify there details. The enlargements of these marginal drawings are as follows: antenna ($\times 67$); anterior tarsus, and anal

ring (×83); body setae, cerarii, and anal lobes (×170); tubular ducts, multilocular, and trilocular disc pores (×333).

Genus MACONELLICOCCUS nov.

GENERIC TYPE: *Maconellicoccus hirsutus* (Green).

COMPOSITION OF THE GENUS: The type is the only included species.

RECOGNITION CHARACTERS: Adult female *Planococcini* with less than 18 pairs of cerarii, normally with 2 cerarian setae in each cerarius; antennae with a pseudo-articulation in the terminal joint giving the appearance of a 9-jointed antenna; anterior leg with unequal tarsal digitules; dorsal body setae flagellate at apex; anal ring with 6 setae; circulus present; small oral collar tubular ducts present on both surfaces and more abundant on venter, oral rim tubular ducts prevalent on dorsum and present on the marginal area of venter.

NOTES: This genus is similar to *Paracoccus* Ezzat and McConnell in being with less than 18 pairs of cerarii, all abdominal cerarii with 2 cerarian setae, and with oral rim tubular ducts. It differs by having antennae with 9-jointed appearance due to a pseudo-articulation in the terminal joint, anterior leg with unequal tarsal digitules, and the small oral collar tubular ducts present on both dorsum and venter though much more numerous on venter.

Therefore, *Maconellicoccus* had to be proposed since the species included could not be referred even to *Paracoccus*, the nearest genus in the tribe *Planococcini*.

Maconellicoccus hirsutus (Green)

1908: *Phenacoccus hirsutus* Green, *Mem. Dept. Agr. India*, p. 25.
1921: *Pseudococcus hibisci* Hall, *Bull. Soc. ent. Egypte*, p. 1.

ADULT FEMALE: Body oval, slightly broader and more rounded anteriorly, average about 2.3 mm. long and 1.5 mm. wide.

Normally with 7 pairs of cerarii, cephalic, thorathic and anterior abdominal pairs absent. All cerarii usually with 2 cerarian setae, those of the anal lobe pair are swollen near base, pointed at apex, about 25 microns long, occasionally a third cerarian setae may be present, with about 6 associated trilocular disc pores and 3 auxiliary setae varying between 25 and 60 microns in length. Anteriorly, the cerarian setae of the three preceding segments are similar in shape to those of the anal lobes but slightly smaller, about 20 microns long. Those of abdominal segments IV and V vary in length between 15 and 25 microns long and frequently one of these setae may become longer, up to about 40 microns long, and less stout; sometimes one cerarian seta only is present on any of the cerarii of segment IV. All cerarii other than the anal lobe pair are without auxiliary setae or any particular association of trilocular disc pores, only about 1 to 3 of these pores are present in the cerarian area.

HEAD: Antennae having a 9-jointed appearance due to the pseudo-articulation of the terminal joint; average measurements, in microns, as follows: I, 45; II, 50; III, 47; IV, 28; V, 40; VI, 36; VII, 34; VIII 35 + 53. Eye base about 12 microns high and 25 microns in diameter. Beak conical, about 150 microns long and 100 microns wide.

THORAX: Legs normal in size; average measurements of posterior leg, in microns, as follows: trochanter, 100 × 58; femur, 226 × 89; tibia, 232 × 41; tarsus, 106 × 30; claw, 35; tarsal digitules, 55; claw digitules, 33; translucent dots few, on posterior femur and on the distal end of posterior tibia, none on coxae. Tarsal digitules of anterior leg are not equal; one is normal, about 55 microns long; the other is more slender and shorter, about 45 microns only. Anterior spiracular apodemes average about 60 microns long and 38 microns wide at atrium; posterior apodemes slightly larger; median portion of apodemes is more than half as wide as atrium.

ABDOMEN: Anal ring nearly apical, about 97 microns in diameter; anal ring setae about 150 microns long. Cisanal and obanal setae long, though shorter than anal ring setae, cisanal about 100 microns long and obanal about 77 microns long. Anal lobe bar distinct, moderately sclerotized, starting from the base of apical seta, sometimes it becomes irregular in shape or broader than a typical planococcine bar; bar setae about 145 microns long, located far of the apical seta by about one third of the bar's length. Apical setae longer than anal ring setae, about 257 microns long and 80 microns wide.

DERMAL STRUCTURES: Ostioles with few trilocular disc pores and setae, posterior pair is slightly prominent; anterior pair with about 9 or 10 pores and 1-3 setae on each lip; posterior pair with about 9-12 pores and 2-4 setae on each lip.

Dorsal body setae stout at basal half and flagellate at apex, with some setae among these shorter and less stout. Ventral body setae longer, less stout and more flagellate.

Trilocular disc pores distributed over both surfaces in the usual pattern, spaced about 3-6 times their diameter on dorsum, more widely spaced on venter except near the spiracular atria where few pores become rather crouded.

Tubular ducts of two types, both present on each surface. The oral rim ducts of dorsum are comparatively large, about 9 microns long, diameter of opening 4-5 microns, of rim about 9 microns, the integument between opening and rim as well as the internal base of the duct are lightly sclerotized, these ducts are numerous, arranged on abdominal segments generally in transverse rows about 1-3 ducts wide, wider toward the marginal areas, and interrupted at the median portion of the segments, while on head and thorax the ducts generally follow the usual pattern of the distribution of setae, approximate numbers as follows : abdominal segments IX, 12; VIII, 20; VII, 10; VI, 26; V, 32; IV, 35; III, 35; II, 36; metathorax, 57; mesothorax, 64; prothorax, 43; head, 18. Oral rim ducts of venter are about three

quarters as large as those of dorsum, fewer in number, and confined to the marginal and sub-marginal areas, approximate numbers as follows: abdominal segments IX, 2; VIII, 4; VII, 3; VI, 5; V, 5; IV, 7; III, 7; II, 6; metathorax, 4; mesothorax, 7; prothorax, 8; head, 2. Oral collar ducts are prevalent and more abundant on venter, about 12 microns long and 3 microns wide, may be smaller at the anterior portions of the segments, arranged on abdominal segments in irregular transverse rows, about 1-3 ducts wide, wider toward lateral margins of segments; on thorax present around coxae and in marginal areas; on head few of these ducts present near anterior margin and on median area; approximate numbers as follows: abdominal segments IX, 23; VIII, 33; VII, 52; VI, 43; V, 39; IV, 26; III, 22; II, 16; metathorax, 25; mesothorax, 34; prothorax, 27; head, 7. The oral collar ducts of dorsum few, similar in size to the smaller ones of venter, arranged in simple, widely spaced segmental rows; approximate numbers as follows: abdominal segments IX, 0 (occasionally 1); VIII, 7; VII, 4; VI, 7; V, 10; IV, 9; III, 7; II, 9; metathorax, 6; mesothorax, 12; prothorax, 6; head, 4.

Multilocular disc pores on ventral surface only, about 7 or 8 microns in diameter, with 10 loculi, arranged in transverse rows 1-2 pores wide, on the anterior and the posterior portions of abdominal segments VI to IX, these rows do not extend into the marginal areas and the number of pores on the anterior portions of each segment is nearly equal to that on the posterior portion of the same segment except in segment VI where the pores on the anterior portion exceed in number those on the posterior portion, some pores present on segment X, very few on segments IV and V, none on abdominal segment II, thorax, and head: approximate numbers as follows: abdominal segments X, 8; IX, 21; VIII, 56; VII, 54; VI, 31; V, 2; IV, 2; III, occasionally 1.

Redescribed from the following mounted adult females: 3 specimens from *Gossypium* sp. (cotton tree), Pusa, India, L.H. G., Feb., 15, 1919; 1 specimen from *Psidium guajava* L., Kantarah, Egypt, April 16, 1940; 2 specimens from *Anona* sp., G.R.F. Medani, Egypt, Feb. 20, 1943; 6 specimens from *Anona* sp., Pyramids, Egypt, Sept. 30, 1947; 2 specimens from *Hibiscus schizopetalus*, Alexandria, Egypt, July 13, 1948; 7 specimens from *Albizzia lebbek* Benth., Giza, Egypt, A. Kotb, June 1956; 2 specimens from *Albizzia lebbek* Benth., Mallawi, Egypt, M. Hafez, July 25, 1956; all in the Coccid Collection of the Ministry of Agriculture, Dokki-Cairo, Egypt; and 2 specimens from *Albizzia lebbek* Benth., Giza, Egypt, A. Kotb, June 1956, in the United States National Collection.

SUMMARY

In this paper, the nomenclatorial status of the so-called "Hibiscus mealybug", *hirsutus* Green, is discussed according to the present concept in coccid taxonomy. Being based upon material examination, the discussion proved that the mealybug

at hand is definitely out of all the Phenacoccine group. *Planococcini* is here considered as the most convenient place for this mealybug. Hence, a new genus, *Maconellicoccus*, had to be proposed within the tribe *Planococcini* to include this species since it could not be referred, without undue violence, to any other genus in the tribe.

The paper also provides, in addition to the recognition characters of the new genus, a detailed illustrated redescription of the species under consideration.

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THE ANATOMY AND HISTOLOGY OF THE MATURE LARVA OF *LIXUS JUNCI* BOH.

[*Coleoptera: Curculionidae*]

(with 38 Text-Figures)

by M. RAMADAN, Ph. D. (1); S.M. HAMMAD, Ph. D. (2);
and A.M. HILMY, M.Sc. (3).

CONTENTS

I. Introduction. — II. Methods and technique. — III. External morphology of the early stages. — IV. Internal anatomy and histology. — V. Summary and conclusions. — VI. Acknowledgments. — VII. References.

I. INTRODUCTION

Lixus junci Boh. (Fig. 1) causes great damage to the beet (*Beta vulgaris* L.) and the leaf-beet (*Beta vulgaris cicla* L.). All the biological stages of this weevil are found on their host plants from March until June. The mode and symptoms of infestation has been fully mentioned by HAMMAD (1956).

In spite of the fact that Curculionidae forms the largest family of the animal kingdom, yet, very few species have been studied in any detail. This made the authors to carry on a comprehensive study of the larva of *Lixus junci* Boh., a species of a very great economic importance.

II. METHODS AND TECHNIQUE

The material for this work, has been collected from at the Alexandria University Experimental Farm. The larvae were fixed in hot BOUIN's fluid for at least

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twelve hours. After washing out the excess of BOUIN by several changes of 70% alcohol, the larvae were transferred to dioxan for about twenty four hours, 3-4 changes being employed. The material was then placed in a mixture of equal amounts of wax and dioxan for about one hour and finally to pure paraffin wax 58°C for about two hours (three changes being used). Sections were cut at a thickness of S-10 microns, stained with EHRLICH'S haematoxylin and counter-stained with eosin.

FIG. 1 : *Lixus junci* Boh., × 4.

The specimens under investigation were dissected under the binocular microscope for studying the different grosser anatomical features.

The tracheal system was made clear through impregnation with Sudan black. The larva was dropped alive in a saturated solution of Sudan black in a mixture of equal parts of olive oil and kerosine, and left in this mixture for about twenty four hours. After such treatment, the tracheae become dark black in colour. Larvae were then dissected and examined in water.

III. EXTERNAL MORPHOLOLY OF THE EARLY STAGES

The egg (Fig. 2) is ovoidal, unsculptured, yellowish in colour, and measures about 1.05 mm. in length and 0.72 mm. in width in its widest part.

The full grown larva (Fig. 3), which is 10 mm. in length and 3 mm. in width in its widest part (third abdominal segment), has been thoroughly described by HAMMAD (1956).

The pupa (Figs. 4 and 5) is about 10 mm. long, and provided with setae and spines. The tips of the wing-pads reach the posterior end of the fourth abdominal sternite. The front legs extend almost to the proximal margin of the first tarsal segment of the middle pair or to the middle region of the metathoracic sternite. The middle pair extends to the distal third of the first abdominal sternite. The hind pair extends to the posterior third of the fourth abdominal sternite. The head is

completely hidden from above by the pronotum. The rostrum is elongated and slender. The antenna is of the geniculate type, extending posteriorly almost to the level of the apex of the rostrum. The abdomen has eight distinct tergites, the seventh tergite being the largest and the eighth the smallest. The abdominal sternites are

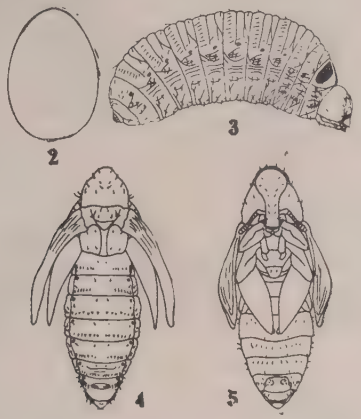

FIG. 2 : Egg of *Lixus junci* Boh., × 22.5. — FIG. 3 : Mature larva of same, × 3. — FIG. 4: Pupa of same, dorsal view, × 3.5. — FIG. 5 : Pupa, ventral view, × 3.5.

nine in number. The seventh sternite has a large lobe with two large setae which are directed forward in the shape of a hook. The last larval skin always remains attached to these two hook-like setae until the hatching of the adult insect. The eighth abdominal sternite has two fleshy processes, each carrying two spines directed upwards.

IV. INTERNAL ANATOMY AND HISTOLOGY

Sections stained by EHRLICH'S haematoxylin allowed the measurements of the various parts of body-wall of the full-grown larva. The epicuticle is 1μ, the exocuticle 10 μ, the endocuticle 22 μ, and the epidermis 7-10 μ high, respectively.

The wing-buds (Fig. 6) are protruded from the body-wall as down-growing folds, just beneath the larval cuticle in both meso-and metathoracic segments.

Similarly, the leg-buds (Fig. 7) project from the body-wall as one single fold of epidermal thickening beneath the larval cuticle in the pro-, meso- and metathorax.

In *Lixus*, the epidermal cells of both buds are composed of about three layers of spindle-shaped cells with deeply stained cytoplasm and nuclei about 4 μ in diameter.

The bud of the two ocelli on each side of the head-capsule, consists of a few elongated epidermal nerve-cells with the over-lying cuticle forming a convex lens.

Figure 8 shows the alimentary canal, the salivary glands and the mycetome of the full-grown larva.

The pharynx (Fig. 9), oesophagus and the crop are about 0.2, 0.15 and 0.48 mm. in diameter, respectively, and they are histologically similar. The cell boundaries are not clear and the nuclei are moderate in size, being about 4 mm. in diameter. The intima is smooth and devoid of any setae. The epithelium of the pharynx is thrown into six folds of nearly equal heights. These folds decrease gradually towards the posterior end where they more or less diminish in the crop. At the point of junction of the fore-gut and mid-gut, there is a rudimentary oesophageal valve (Fig. 10).

FIG. 6 : Transverse section of the wing-bud, × 125. — FIG. 7 : Transverse section of the leg-bud, × 175. — FIG. 8 : Mature larva showing the alimentary canal, salivary glands and mycetome, × 3.5. — FIG. 9 : Transverse section of the pharynx, × 125. — FIG. 10 : Lateral section at the junction of the fore-gut and mid-gut, × 18. — FIG. 11 : Transverse section of the mid-gut and mycetome, × 8. — FIG. 12: Lateral section at the junction of the mid-gut and hind-gut, × 75. — FIG. 13: Transverse section of the ileum, × 237.5. — FIG. 14 : Transverse section of the colon, × 82.5. — FIG. 15 : Transverse section of the rectum, × 125. — FIG. 16 : Lateral section of the anal sphincter, × 50.

(*Ansph*, anal sphincter; *Ca*, caecum; *c.m.*, circular muscles; *Co*, colon; *Cr*, crop; *ctm*, connective tissue membrane; *Cu*, cuticle; *Ep*, epidermis; *IL*, ileum; *In*, intima; *Lb*, labrum; *Lm*, labium; *Md*, mandible; *Mg*, mid-gut; *MT*, Malpighian tubes; *Mx*, maxilla; *My*, mycetome; *n*, nerve-cells; *per.m.*, peritoneal membrane; *r.c.*, replacement cell; *Rec*, rectum; *Sg*, salivary glands; *Tr*, trachea).

The musculature of the fore-gut of *Lixus* is composed of a thin circular muscle layer, about 14 μ in thickness.

The mid-gut begins as a long wide sac, about 1.5 mm. in diameter in its widest part, passing straight backwards, then narrowing posteriorly becoming tubular in shape, and measuring about 0.3 mm. in diameter. Associated with the hinder end of the narrow part of the mid-gut, are two pairs of tubular intestinal caeca about 0.3 mm. in diameter.

The epithelial cells of the mid-gut (Figs. 10 and 12) are columnar or cubical, being about 49 μ high with nuclei about 12 μ in diameter, with deeply stained regenerative cells scattered chiefly at their bases. Internally, the epithelial cells are bounded by a striated border. The contents of the mid-gut are invested by a peritrophic membrane.

The mid-gut contains few micro-organisms living free in its lumen. These micro-organisms are composed mostly of cocci, either single or in chain, together with few rods.

The musculature of the mid-gut is composed of an inner circular muscle coat and an outer longitudinal one.

A mycetome (Fig. 8, My) composed of four masses of cells is to be found around the mid-gut sac (Fig. 11). Each mass is about 0.2 mm. long and 0.07mm. in diameter. It is formed of many cells confined to the wall and with a large vacuole in the centre. The cell has a granulated cytoplasm and a small nucleus about 6 μ in diameter. Stained smears of these masses proved that they contain very few coccoid-form micro-organisms.

The hind-gut is about 0.3 mm. wide. Seven delicate pairs of muscles are inserted on the dorsal and ventral walls of the hind part of the rectum and arise on the body-wall of the ninth abdominal segment.

The pyloric region (Fig. 12) is represented by a ring of small epithelial cells at the anterior end of the ileum immediately behind the opening of the Malpighian tubes. The inner ends of these cells are covered with a smooth cuticular intima. This ring of cells encloses a wide chamber which begins behind the mid-gut and is covered externally by a circular muscle layer continuous with that over the ileum. These circular muscles together with the longitudinal muscles present at the posterior end of the mid-gut regulate the closing and opening of the pyloric valve respectively. The peritoneal membrane of the Malpighian tubes extends to some extent to envelop the muscular sheath of the pyloric region.

In the ileum (Fig. 13), the epithelial cells are exceedingly thin and irregularly folded slightly inwards. These cells are about 4 μ high in its widest part, with nuclei about 4 μ in diameter. The intima is smooth. The ileum is coated by a circular muscle layer about 14 μ broad.

The epithelium of the colon (Fig. 14) is also irregularly folded slightly inwards. It is composed of larged flat cells that are about 8 μ high in its highest part, with nuclei about 6 μ in diameter. These cells are comparatively large than those

of the ileum and rectum. The colon has a very thin circular muscle layer, about 4 μ wide.

A cross-section in the rectum (Fig. 15) shows that it is composed of more or less flattened cells about 8-10 μ high in its highest part, with nuclei about 8 μ in diameter, lined internally by a smooth intima and enveloped externally by two muscle layers, an internal one about 4-8 μ thick, and an external muscle layer which is composed of six separate muscle-bands distributed regularly around the circular muscle layer. Each band is about 7 μ thick. The crypto nephric part of the Malpighian tubes are observed scattered outside the muscular sheath of the rectum. A connective tissue-membrane invests the cryptonephric region of the Malpighian tubes.

The anal sphincter (Fig. 16) is a tube about 0.6 mm. long and 0.12 mm. in diameter, following the rectum and ending in the anal aperture. It is an invagination of the body-wall and is covered externally by a thick layer of circular muscles about 30 μ thick.

In most Coleoptera, there are three pairs of Malpighian tubes each is about 0.1 mm. in diameter, arising between the mid-gut and hind-gut and ending in the walls of the rectum. Two of these six tubes are confined to the posterior end of the body while the other four extend for different distances along the sides of the mid-gut.

A cross-section in the basal part of the tube (Figs. 17-18) shows that it is composed of about four cells, which are about 25 μ high with nuclei about 8 μ in diameter. These cells have a granular cytoplasm with some secretions surrounding the nuclei. The lumen of the tube is rather wide. The number of cells decreases towards the posterior end of the tubes. In a further section of the tube, the cells are also granular, being about 40 μ high in its heighest part, with nuclei about 25 μ wide and 15 μ high, with more secretion embedded in their cytoplasm. The lumen is very narrow and the striated border is comparatively shorter than that of the basal part.

The salivary glands show a pair of simple tubes which open each separately in the maxilla of its corresponding side. They extend along the ventral side of the body cavity until they reach the posterior end of the second thoracic segment (Fig. 8). In its widest part, each tube is about 56 μ in diameter and it narrows gradually and slightly towards its external opening on the maxilla. The tube is invested in a peritoneal coat and is composed of large cubical epithelial cells which are about 25 μ high with nuclei about 12 μ high and 17 μ broad (Figs. 19 and 20). The cytoplasm of these cells is granular with numerous striations near the lumen border. There is a cuticular intima lining the whole tube.

In the full-grown larva (Fig. 21) there are nine pairs of functional spiracies (Sp) situated on the prothoracic and first eight abdominal segments. Each spiracle, opens into a very short spiracular trachea (Sp. Tra) which in turn opens into the main lateral trachea (ML. Tra). There are two main lateral tracheae, one on either side of the body of the mature larva and extending from the prothoracic segment to the tenth abdominal segment.

From the anterior extremity of each main lateral trachea, arise two large tracheae to the head-capsule, the so-called dorsal cephalic trachea (Dc. Tra) which supplies the dorsal and middle regions of the head-capsule with the dorsal side of the prothorax, and the ventral cephalic one (Vc. Tra) which supplies the lower and middle parts of the head-capsule including the mouth parts. In the prothorax, there occurs a very short spiracular trachea opening into the prothoracic spiracle, dorsal thoracic tracheae and their branches supplying the dorsal side of the pro- and meso-thorax and finally the ventral thoracic tracheae providing the ventral side of the pro- and mesothoracic segments.

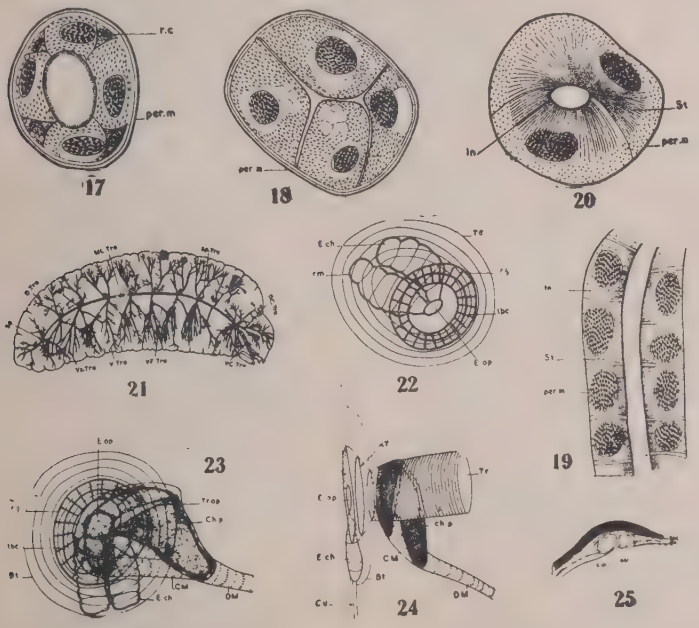

FIG. 17 : Transverse section of the distal region of the Malpighian tube, × 250. — FIG. 18 : Transverse section of the basal region of same, × 250. FIG. 19 : Lateral section of the salivary gland, × 250. — FIG. 20 : Transverse section of the salivary gland, × 500. — FIG. 21 : Tracheal system of the mature larva, × 3.5. — FIG. 22 : Frontal view of the spiracle, × 150. — FIG. 23 : Inner view of same, with the closing apparatus, × 150. — FIG. 24 : Lateral view of the spiracle and of the closing apparatus, diagramatic, × 150 — FIG. 25 : Transverse section of the external chambers, × 150. — Lettering as in Text.

In the metathoracic segment there arise dorsal thoracic tracheae which supply the dorsal side of the meta- and mesothoracic segments, and a ventral branch which runs posteriorly to communicate with a similar branch in the first abdominal segment. From the ventral trachea of the metathorax, arises a branch which runs anteriorly to provide the mesothoracic segment.

In addition to the branches arising in the pro- and metathorax, the main lateral trachea also sends off lateral segmental tracheae along its total length, the dorsal segmental tracheae (D. Tra) supplying the dorsal side of the abdominal segments and all their contents of the internal systems. The ventral segmental tracheae (V. Tra) in each of the first six abdominal segments is divided into two main branches. The anterior branch runs anteriorly to join the posterior main ventral branch of the preceding segment. The posterior branch runs slightly towards the posterior side to join the anterior branch of the next segment. Both the posterior and anterior branches of every two adjacent segments form a V-shaped loop (Vf. Tra). In the seventh abdominal segment, the ventral segmental trachea is also divided into two main branches, the anterior branch runs anteriorly to form a loop with the posterior branch of the ventral segmental trachea of the six abdominal segment. On the other hand, the posterior branch runs posteriorly without forming any loop. In the eighth abdominal segment, this ventral segmental trachea is bifurcated while it is single in the ninth abdominal segments.

Some visceral tracheae (Vs.Tra) arise from the main lateral longitudinal branch, at the points of emergence of the ventral segmental tracheae. These visceral branches run inwards to supply mainly the alimentary canal, fat bodies and the oenocytes.

The spiracle (Figs. 22, 24 and 25) is biforous and consists of two external chambers (E.ch) opening into the atrium. Each external chamber possesses a dorsal slit which opens to the exterior along its axis. There is also a primary atrial opening (E.op.) which is completely closed except during ecdysis. The external chambers are attached along their margins to the larval cuticle by a chitinous rim (r.m). The lateral and inner walls of each chamber are strengthened by transverse, semi-circular chitinous annuli.

The atrial chamber (AT) is formed of an outer part which narrows towards its inner end where it opens into the inner part of the atrium. The walls of the outer part are strengthened by three chitinous rings (rg), which are joined together by cuticular trabeculae (tb). The inner part of the atrial chamber has the walls strengthened by a spiral thickening.

Surrounding the spiracle is a basket (Bt) which is attached to the cuticle at its outer end and to the atrial chamber at its inner end. The walls of the basket are strengthened by separate taenidia (Td).

The spiracular closing apparatus (Figs. 23 and 24) consists of a chitinous plate (Ch.p) formed of two arms, unequal in length, and transverse sclerite joining the two broad upper ends of these arms. The occlusor muscle (CM) is found attached between the distal ends of the two arms of the chitinous plate while the dilator muscle (DM) is inserted on the outer side of the long arm opposite the attachment of the occlusor muscle. When the occlusor muscle contracts, the two arms become nearer to each other; so that the narrow opening of the trachea (Tr.op) is completely closed. On the other hand, when the dilator muscle contracts, the two arms become separated, thus opening the trachea.

In the nervous system (Fig. 26) the ventral nerve cord extends to the posterior end of the first abdominal segment and comprises a sub-oesophageal ganglion, three thoracic ganglia and a chain of nine abdominal ganglia.

From the sub-oesophageal ganglion arises nerves to the mouth appendages as well as to the anterior part of the first thoracic segment. The first thoracic ganglion emits two pairs of branched nerves which supply the prothorax. Each of the second and third thoracic ganglion has only one pair of branched nerves, each innervating its own segment. From each abdominal ganglion, except the ninth one, is given off

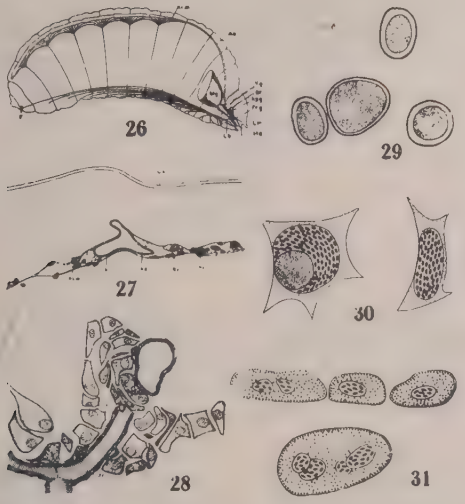

FIG. 26 : Mature larva showing the circulatory and nervous system, × 3.5. — FIG. 27 : Transverse section of the heart, × 25. — FIG. 28 : Oenocytes.—FIG. 29 : Blood cells non phagocytes, ×100. — FIG. 30 : Blood cells phagocytes, × 100. — FIG. 31 : Pericardial cells, × 100.

(*Ad*, adventitia; *ALm*, alary muscles; *Ao*, aorta; *Bc*, blood cells; *Br*, brain; *F*, female imaginal disc; *Fr.g*, frontal ganglion; *h*, heart; *hy.g*, hypocerebral ganglion; *V.g*, ventricular ganglion. — Other lettering as mentioned before).

a pair of single nerves. Each pair of nerves, radiating from the first six abdominal ganglia, supplies the corresponding abdominal segment. The nerves of the seventh abdominal ganglion innervate the six abdominal segment. Similarly, the single pair of nerves arising from the eighth abdominal ganglion goes to the seventh abdominal segment. From the terminal abdominal ganglion, are given off two pairs of nerves innervating the eighth, ninth and tenth abdominal segments respectively.

The brain is about 0.4 mm. wide.

The parts of the stomadaeal nervous system that have been distinguished are shown in Figure 26.

The wall of the heart (Fig. 27) consists of bundles of circular muscles. An adventitia closely invests the heart and the proximal portion of the aorta.

The pericardial septum contains six pairs of delicate alary muscles formed of striated muscle fibres.

Two types of blood cells, or leucocytes are present in *Lixus junci*. The first type (Fig. 29) is found in great number. The diameter of each cell ranges from 1-10 μ. Their cytoplasm is hyaline and non-vacuolated. Each cell has a comparatively big rounded nucleus which almost fills it. The second type (Fig. 30) is amoeboid in shape. Its cytoplasm is packed with deeply stained granules. Each cell is about 7 μ in diameter with a nucleus about 4 μ in diameter. It differs from the first type in being larger in size and less in number.

The pericardial cells occur as cell-masses on each side of the heart and base of aorta with distinct cell boundaries between the cells. They are more or less ovoid in shape and are about 18 μ long and 14 μ wide (Fig. 31). They have finely granulated and non-vacuolated cytoplasm. Each cell usually contains one, occasionally two or even four nuclei, each about 4 μ in diameter.

The fat-body is confined to the thorax and abdomen. As in most other insects, it is differentiated into two layers: (1) a parietal layer between the epidermis and the muscle coat, (2) a visceral layer which occupies a great part of the perivisceral cavity.

Each fat-body cell is about 35-50 μ in diameter with rounded nuclei about 15 μ in diameter, its cytoplasm is heavily vacuolated with globules of oil like fat. Other granules are also present in the meshes of the vacuolated protoplasm. A connective-tissue membrane is seen to be investing this whole structure.

The oenocytes (Fig. 28) are confined to the first eight abdominal segments. They form a clump of cells between the spiracles and the main lateral trachea on both sides of the body. These groups of cells vary in number, being about thirty six in the first abdominal segment and decrease gradually in number until they become very few in the eighth abdominal segment. In each group, the cells adhere closely to one another.

In the musculature of the mouth-parts there are two pairs of labial muscles (Fig. 33) as follows : (1) the first pair, the levator muscles (l. Prmt), which originates on the posterior margin of the tentorium and inserted dorsally on the posterior border of the prementum; (2) the second pair, the depressor muscle (d. Prmt) originating also on the Posterior margin of the tentorinm and inserted dorsally on the anterior border of the prementum.

The cranial muscles (Fig. 34) consist of some levator muscles (L. cap) originating on the prothoracic sternite and some depressor muscles (d.cap) originating on the anterior third of the prothoracic tergite.

All the following described muscles concern only one side of the body-wall.

Immediately below the epidermis, there are five slender lateral transverse muscle bands (L.Trv) in each of the first nine abdominal segments. In each of the thoracic segments, there are only three lateral transverse muscle sets.

Just below these lateral transverse muscle sets, there is a set of longitudinal

muscles (Fig. 35) which is situated dorso-laterally (D.LM) and another longitudinal muscle set situated ventro-lateraly (V.LM) on each side of the body-wall.

The external oblique muscles are contained wholly in the ventral side of the body-wall (Fig. 35). They are composed of anterior series (Av. Ex.ob.M) and another posterior one (Pv.Ex.ob.M).

The internal oblique muscle bands (Fig. 36) are divided into dorsal oblique muscles and ventral oblique ones. The dorsal oblique muscles may be, for convenience, divided into anterior bands (AD.ob.M) and the posterior bands (PD. ob.M) The ventral oblique muscles are also composed of the anterior bands (Av. In.ob.M) and the posterior ones (PV.In.ob.M).

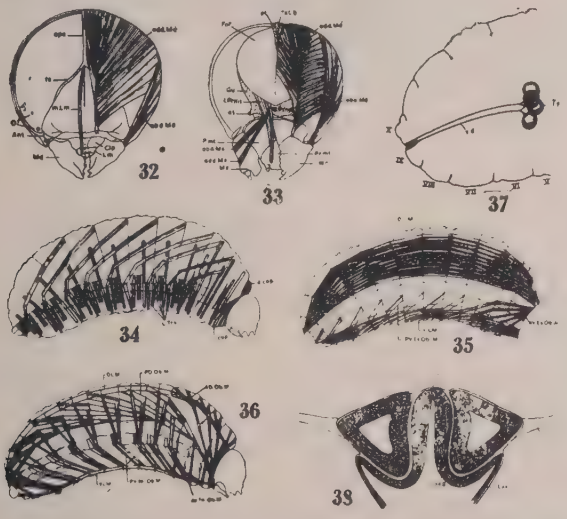

FIG. 32: Dorsal view of head-capsule (various parts removed to show musculature of mouth-parts), × 17.5. — FIG. 33 : Ventral view of same, × 17.5. — FIG. 34 : Lateral view of a larva to show the cranial and lateral transverse muscles, × 3.5. — FIG. 35 : Lateral view of same showing the longitudinal muscles and the external oblique muscles, × 3.5. — FIG. 36 : Lateral view of a larva showing the internal oblique muscles and other two bands of longitudinal muscles, × 3.5. — FIG. 37 : Imaginal disc of the male reproductive organs, × 18. — FIG. 38: Lateral section of the imaginal disc of the female reproductive organs, × 125.

(*Ant*, antenna; *at*, anterior tentorial pit; *Clp*, clypeus; *Epd.I-Epd.III*, epidermal cells; *eps*, epicranial suture; *For*, occipital foramen; *Fs*, frontal suture; *Gu*, gula; *LC*, luminated cord of epithelial cells; *Lm*, labrum; *Md*, mandible; *Mx*, maxilla; *n*, nerve; *O*, ocelli; *Pont*, post-mentum; *Prmt*, pre-mentum; *pt*, posterior tentorial pits; *Tet. B*, tentorial bridge; *Ts*, testes; *v.d.*, vas deferens; *V-X*, abdominal segments 5-10. — Other lettering as in Text).

There are two longitudinal muscle bands, one dorsal (DLM) and another ventral (VLM) extending from the prothorax until the tenth abdominal segment (Fig. 36). The anterior series lies internal to the internal oblique muscles in the prothorax only.

The imaginal discs of the male reproductive system (Fig. 37) in the larva of *Lixus junci* is composed of two joined rounded testes which occur in the abdomen on either side. The two testes are connected with a vas deferens which is attached to the body-wall between the ninth and tenth abdominal segments. The testis which is about 0.25 mm. in diameter, reaches the anterior margin of the sixth abdominal segment.

The imaginal discs of the female reproductive organs (Fig. 38) in the mature larva is developed as an ectodermal invagination between the ninth and tenth abdominal sternites. It projects into the body-cavity as a bilobed structure about 0.2 mm. long and 0.3 mm. wide in its widest part, with a connection between the two lobes. At the basal part of the invagination, the epidermal cells are arranged in a thin layer, but this becomes thicker inwards situated dorso-laterally to this thick walled region are two cords of epithelial cells which had a distinct lumen and are quite separate from the rest of the female imaginal disc. The whole structure is invested in a sheath of connective-tissue membrane.

V. SUMMARY AND CONCLUSIONS

1. — Investigations have been made on the structure of the mature larva of *Lixus junci*.

2. — The external morphology of the immature stages: the egg, larva and the pupa, have been described.

3. — A detailed account of each system in the mature larva was described.

4. — The structure of the body-wall, wing- and leg-buds and ocelli have been given.

5. — The alimentary canal with its main divisions has been studied in full detail.

6. — The salivary glands are in the form of a pair of simple tubes which open each separately in the maxilla.

7. — The tracheal system in the mature larval is fully described. The position, number and structure of the biforus spiracles were given in detail. Also, the structure of the closing-apparatus is given.

8. — The central as well as the stomodaeal nervous system were thoroughly worked out.

9. — The circulatory system comprising the heart, aorta and the associated structures were studied. The heart has six chambers, six pairs of ostia and six pairs of alary muscles. Its wall consists of circular muscle fibres. An adventitia invests the heart and base of aorta. The dorsal sinus contains fat body, two types of blood cells and pericaridial cells.

10. — The oenocytes in the mature larva form a clump of cells between the spiracles and the main lateral trachea on both sides of the body.

11. — The musculature of the mouth parts cranial muscles and the body musculature are described in detail.

12. — A detailed study of the imaginal discs of the reproductive organs of both sexes in the mature larva has been made.

VI. ACKNOWLEDGMENTS

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SOIL ARTHROPOD FAUNA OF AN ONION FIELD, WITH AN EVALUATION TO EXTRACTION METHODS USED

(with 3 Text-Figures and 6 Tables)

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I. INTRODUCTION

Adopting the flotation method, the writer (1957) illustrated the status of the arthropod fauna throughout the year under several crops and vegetables. In the present attempt, another crop, the onion, was selected to study the states of the arthropods in the soil underneath, using the above method as well as the TULLGREN-funnel method. Comparing these two methods of extraction under our Egyptian conditions, it would be possible to choose the preferable method for treating any one group in future soil faunal arthropod problems. The flotation method was pioneered by LADELL (1936), advocated and more or less improved by STRICKLAND (1944), SALT and HOLLICK (1944) and COCKBILL et AL. (1945). The dry method was illustrated by TRAGARDH (1933), modified and improved by HAARLOV (1947) and SENGBUSCH (1956). Both methods were discussed by LADELL (1936), STRICKLAND (1944), KÜHNELT (1955) and MACFADYEN (1955).

The aim of the present paper is, therefore, to throw light on two main points: (1) the magnitude and kind of the soil arthropod fauna met with in an onion field; (2) the effeciency of the two extraction methods adopted.

II. PROCEDURE

Fourty samples were obtained in pairs at random from an onion field during March 1956. The crop was in bloom. One sample of each pair (20 samples in all)

was treated by the TULLGREN-funnel method. The fauna of each sample was examined and estimated after being kept in the funnel for 24 hours. The other twenty samples were treated by the flotation method described by the writer (1957). The sample was a core of four inches in diameter and fifteen inches in height below the soil surface.

III. EXPERIMENTAL RESULTS

Main arthropod groups

No members of *Onychophora* or *Crustacea* were met with denoting their absence or scarcity. Means of other arthropod groups found are shown in Figure 1 and Table I. The mean numbers obtained by the two methods showed that the insect

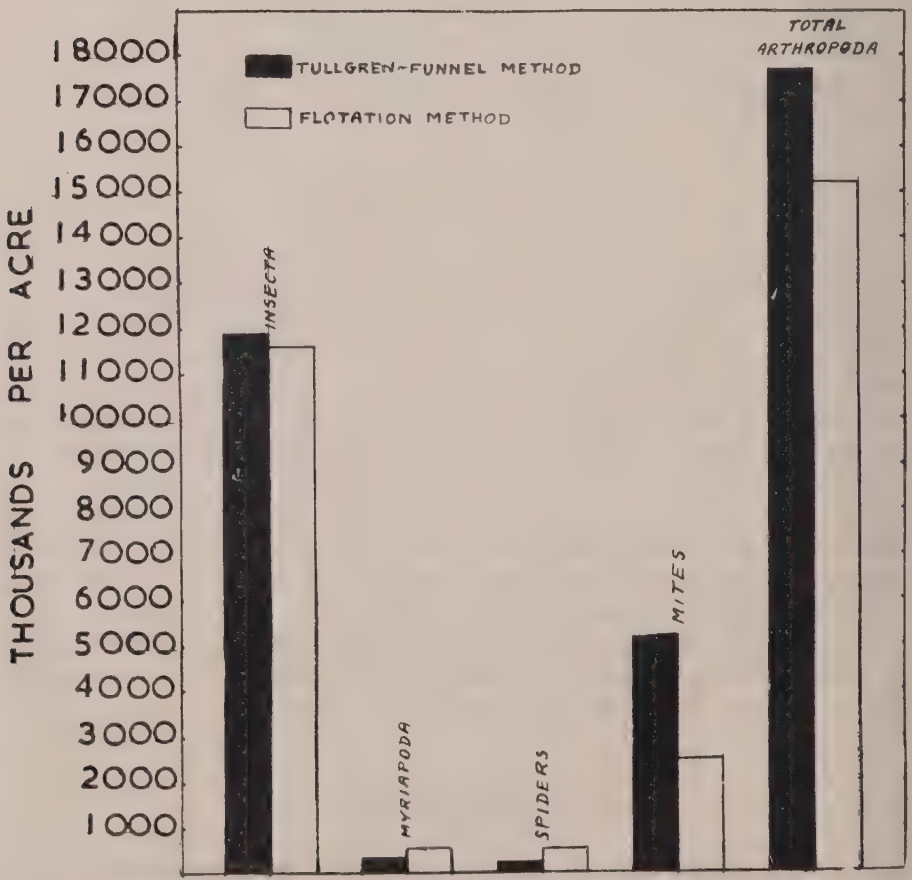

FIG. 1: Means per acre of main arthropod groups.

means were the highest while the mite means were next in magnitude. The total number of mites obtained by the TULLGREN funnel were nearly twice the number obtained by the flotation method. The reverse actually happened in the case of both myriapods and spiders.

In the case of the TULLGREN-funnel, the maximum number per acre per sample was 32.000.000 arthropod specimens, 25.500.000 insects, 1.000.000 myriapods, 1.000.000 spiders and 13.000.000 mites. In the case of the flotation method the maximum number per acre per sample met with was 37.000.000 arthropod specimens, 32.500.000 insects, 2.000.000 myriapods, 4.000.000 spiders and 9.000.000 mites.

The number of individuals obtained in the 20 samples and their relative percentages to the total number of arthropods are recorded in Table I. Myriapoda and spiders composed, each, a small fraction of the total arthropod soil fauna. By both methods of extraction the insect percentages exceeded considerably the mite percentages.

TABLE I

Main arthropod groups of an onion field in 1956.

Main arthropod groups	Tullgren-funnel method			Flotation method		
	Mean per acre in thousands	Total number in 20 samples	Percentage	Mean per acre in thousands	Total number in 20 samples	Percentage
Insecta ...	11900	476	67.04	11650	466	76.39
Myriapoda	350	14	1.97	550	22	3.61
Spiders	250	10	1.41	550	22	3.61
Mites	5250	210	29.59	2500	100	16.39
Total ...	17750	710	100.00	15250	610	100.00

Insect fauna

Means per acre of insect groups are recorded in Figure 2 which shows their relative abundance in the soil. The number and percentages of the insect groups obtained are recorded in Table II.

From Figure 2 and Table II the following remarks could be deducted :

COLLEMBOLA: The superiority of the TULLGREN-funnel method in extracting soil Collembola is very clear (Fig. 2). The flotation method seems to be unsuitable for extracting such delicate insects. The maximum number per acre obtained by the former method was 11.500.000 specimens while it was 5.500.000 specimens by the latter method. Collembola extracted by the TULLGREN-funnel composed more than 50% of the total insect fauna. This percentage was less than 20% in the case of the flotation method.

The springtails extracted belonged entirely to the sub-order *Arthropleona*. Both the *Poduromorpha* and the *Entomobryomorpha* were represented but the

former forms were more dominant. Specimens belonging to the genus *Onychiurus* were most numerous.

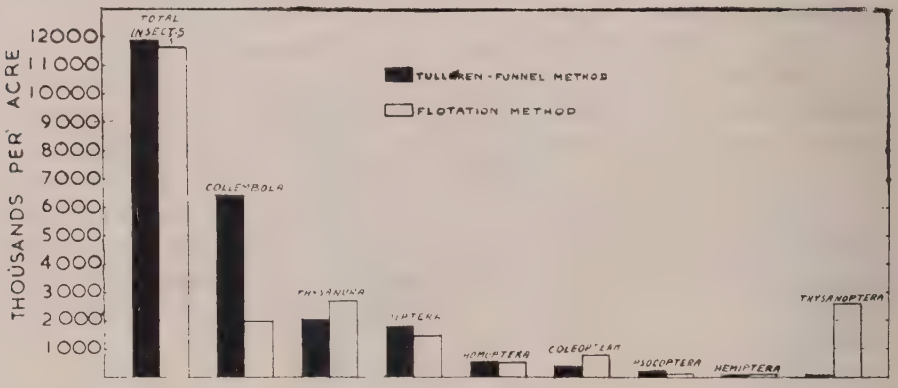

FIG. 2: Means per acre of main insect orders met with in the soil of an onion field.

THYSANURA: This group made up about one-fifth of the total soil insect fauna. The number obtained by the flotation method was somewhat higher. The maximum number per acre obtained at any occasion by this method was 2.750.000 specimens. This number reached 2.100.000 specimens by the TULLGREN-funnel.

TABLE II

Insect fauna of an onion field in 1956.

Orders	Tullgren-funnel method			Flotation method		
	Mean per acre in thousands	Total number in 20 samples	Percentage	Mean per acre in thousands	Total number in 20 samples	Percentage
Collembola	6450	258	54.20	2000	80	17.17
Thysanura	2100	84	17.65	2750	110	23.61
Diptera	1850	74	15.55	1500	60	12.88
Homoptera	600	24	5.04	575	23	4.94
Coleoptera	450	18	3.78	800	32	6.87
Psocoptera	250	10	2.10	150	6	1.29
Hemiptera	100	4	0.84	125	5	1 07
Thysanoptera	100	4	0.84	2600	104	22.32
Neuroptera	—	—	—	25	1	0.21
Hymenoptera	—	—	—	1100	44	9.44
Microlepidoptera	—	—	—	25	1	0.21
Total	11900	476	100.00	11650	466	100.00

The specimens obtained belonged to two genera, viz : *Heterojapyx* and *Anajapyx*. Individuals representing the former genus were more prevailing as they composed 95.2% (TULLGREN-funnel method) or 92.7% (flotation method) of the total thysanurans.

DIPTERA: This order represented about 12-15% of the total insect fauna. Table III shows the status of the dipterous fauna obtained. The superiority of extracting the adult stages by the TULLGREN-funnel is very clear. The larvae and pupae were exclusively obtained by the flotation method.

TABLE III

Dipterous fauna of an onion field in 1956

Dipterous fauna	Tullgren-funnel method			Flotation method		
	Mean per acre in thousands	Number in 20 samples	Percentage	Mean per acre in thousands	Number in 20 samples	Percentage
Mycetophilidae	450	18	24.3	150	6	10.0
Bibionidae	350	14	18.9	50	2	3.3
Culicidae	400	16	21.6	50	2	3.3
Chironomidae	300	12	16.2	—	—	
Psychodidae	200	8	10.8	50	2	3.3
Other flies	150	6	8.2	—	—	—
Larvae	—	—	—	150	6	10.0
Pupae	—	—	—	1050	42	70.0
Total	1850	74	100.0	1500	60	100.0

The maximum number per acre obtained at any occasion was 3.500.000 specimens by the Tullgren-funnel and 1.500.000 specimens by the flotation method. Dipterous pupae composed about 70% of the total dipterous fauna in the case of the flotation method. By this method only 12 flies were obtained from 20 samples while 74 flies were extracted by the other method.

HOMOPTERA: This order represented about 5% of the soil insect fauna. The two methods seemed to be equally suitable for extraction of this group. The maximum number per acre obtained at any occasion was, however, 4.500.000 specimens by the TULLGREN-funnel and 1.500.000 specimens by the flotation method. The forms obtained belonged to two families, viz. *Aphidae* and *Coccidae*. About 84.6% of the specimens belonging to the former family were extracted by the flotation method while all the members of the latter family were extracted by the TULLGREN-funnel method and were all in the nymphal stage.

COLEOPTERA : Figure 2 and Table II show the status of coleopterous fauna among the other groups of insects. The number of coleopterous specimens obtained by the flotation method was nearly twice that obtained by the Tullgren-funnel method. This phenomenon is very clear in the case of beetles as shown in Table IV.

TABLE IV

Coleopterous fauna.

	Tullgren-funnel method			Flotation method		
	Mean per acre in thousands	Number in 20 samples	Percentage	Mean per acre in thousands	Number in 20 samples	Percentage
Adults	250	10	55.56	550	22	68.75
Larvae	200	8	44.44	250	10	31.25
Total	450	18	100.00	800	32	100.00

Specimens belonging to the family *Staphylinidae* were more prevailing while those belonging to the family *Dermestidae* were next in magnitude.

Beetles obtained are classified as follows:

Staphylinidae: *Philonthus* sp., *Platysthethus cornutus* Grav., *Platysthethus* sp.

Dermestidae: *Trinodes flavus* Motsch., *Anthrenus minor* Woll., *A. verbasci* L., *Attagenus piceus* Oliv. and *A. sordidus* Heer.

Lathridiidae: *Corticaria fulva* Com.

Anobiidae: *Lasioderma serricorne* Fabr.

Hydrophilidae: *Cercyon quisquilius* L.

PSOCOPTERA : This insect group composed a relatively small fraction (Fig. 2 and Table II). Specimens obtained represented only one species, viz. *Liposcelis diverticulus* which belongs to the family *Liposcelidae.*

HEMIPTERA : This order composed only a small fraction of the soil insect fauna. Some of the specimens of this order are only found accidently in the soil and are called "Geoxenes or Stays" by JACOT (1940).

Hemipterous fauna met with were *Jassidae* and *Myridae* (*Trignotylus brevipes* Jak. and *Campylomma nicolasi* Put.-Reut.).

THYSANOPTERA : Individuals obtained were entirely *Thrips tabaci.* Counts procured by the flotation method were markedly *very higher* as compared by those obtained by the TULLGREN-funnel method. While the maximum number per acre met with at any occasion was 500.000 specimens by the latter method, it was 14.500.000 specimens by the former method. This may be due to newly dead specimens fallen from the onion plants into the soil and extracted by the flotation method.

NEUROPTERA, HYMENOPTERA and MICROLEPIDOPTERA : From the 20 samples treated by the flotation method, only one specimen was extracted. It represented the genus *Coniopteryx* (*Coniopterygidae*) belonging to the order *Neuroptera.* Another single specimen was also extracted by this method and was a representative of the *Microlepidoptera* (Table II).

As to *Hymenoptera,* only two adult specimens were obtained from the 20 samples treated by the flotation method and they belonged to the family *Cynipidae.*

The other 42 specimens obtained also by this method were dense masses of pupae (*Braconidae* ?) (Table II).

No members of these three families were obtained by the TULLGREN-funnel.

Myriapoda

Only Symphylids were obtained and they represent the genus *Scutigerella*. Figure 1 and Table II show that the flotation method was more suitable for extracting these animals.

The maximum number per acre met with at any occasion was 1.000.000 specimens in the case of the TULLGREN-funnel and twice this number in the case of the flotation method.

Spiders

The number of spiders extracted by the flotation method was nearly twice that obtained by the TULLGREN-funnel method (Fig. 1 and Table I). The maximum number per acre met with at any occasion was 1.000.000 specimens by the latter method and 4.000.000 specimens by the former method.

Spiders extracted belonged to the order *Araneomorpha*, section *Ecribellatae*.

Mite fauna

Mites (Fig. 1 and Table I) were next in magnitude to insects. The number obtained by the TULLGREN-funnel method was nearly twice that extracted by the flotation method. Regarding the 20 samples treated, the maximum number per sample obtained by the TULLGREN-funnel was 27 specimens (or 13.500.000 specimens per acre). By the flotation method, the maximum number per sample was 18 specimens (or 9.000.000 specimens per acre).

TABLE V. — *Mite fauna.*

Fauna	Tullgren-funnel method			Flotation method		
	Mean per acre in thousands	Number in 20 samples	Percentage	Mean per acre in thousands	Number in 20 samples	Percentage
Phthiracaridae	100	4	1.9	900	36	36.0
Lohmaniidae	1250	50	23.8	250	10	10.0
Epilohmaniidae	150	6	2.8	125	5	5.0
Eremaeidae	450	18	8.6	300	12	12.0
Pterogasterina	550	22	10.5	400	16	16.0
Acaridae	300	12	5.7	150	6	6.0
Nanorchestidae	1250	50	23.8	50	2	2.0
Other Trombidiformes	850	34	16.2	150	6	6.0
Gamasides	350	14	6.7	175	7	7.0
Total mites	5250	210	100.0	2500	100	100.0

Means per acre of the different mite groups are shown in Figure 3 and the numbers obtained together with the percentages are recorded in Table V. Among the soil mites, *Oribatei* composed the largest fraction, reaching about 50.6% by the TULLGREN-funnel method and about 79% by the flotation method. With the only

FIG. 3: Means per acre of main mite groups met with in the soil of an onion field.

exception of the Phthiracardid group, the TULLGREN-funnel showed its superiority over the flotation method for extracting soil mites. Perhaps most of the Phthiracaridid mites remain quiescent in the soil under unsuitable environmental conditions such as light, heat or dessication.

IV. CONCLUSION

Onychophora and crustacean specimens were not met with in the soil of the onion field examined. Members of these two classes were also absent in the soil of the six fields examined previously during the year 1951-1952 (EL-KIFL, 1957). This shows that such specimens are either absent or very scarce in the cultivated land at Giza.

Other arthropods were found by millions per acre; reaching in the case of the TULLGREN-funnel method 17.75 million arthropod specimens per acre and 15.25 millions in the case of the flotation method. As to magnitude, Insecta extracted by the two methods stood first reaching 11.9 millions and 11.65 millions per acre respectively. Mites were next in magnitude, composing 5.25 millions and 2.5 millions per acre respectively. Both Myriapoda and spiders made a small fraction of the arthropod fauna being 3.38% or 7.22% of the total arthropods by the two methods respectively.

Collembola and Thysanura collectively composed a large fraction of the soil arthropod fauna. In the case of the TULLGREN-funnel, collembolans alone composed 54.2% of the total insects while this percentage dropped to 17.17% by the flotation method. Specimens of these two orders composed 71.85% of the total insects by the former method and 40.78% by the latter method. Concerning the TULLGREN-funnel method, Diptera, Homoptera and Coleoptera were next in importance, representing

TABLE VI. — *Number and relative percentages of arthropod fauna extracted by both methods.*

Fauna	Number obtained by			Percentages		
	Tullgren funnel method	Flotation method	Total	Tullgren funnel method	Flotation method	Total
Collembola	258	80	338	76.3	24.7	100
Thysanura :						
Heterojapyx	80	102	182	44.0	56.0	100
Anajapyx	4	8	12	33.3	66.7	100
Diptera:						
Adults	74	12	86	86.0	14.0	100
Larvae	—	6	6	—	100.0	100
Pupae	—	42	42	—	100.0	100
Homoptera :						
Aphids	14	23	37	36.8	62.2	100
Coccidae nymphs	10	—	10	100.0	—	100
Coleoptera :						
Adults	10	22	32	31.3	68.7	100
Larvae	8	10	18	44.4	55.6	100
Psocoptera	10	6	16	62.5	37.5	100
Hemiptera	4	5	9	44.4	55.6	100
Thysanoptera	4	104	108	3.7	96.3	100
Neuroptera	—	1	1	—	100.0	100
Hymenoptera :						
Adults	—	2	2	—	100.0	100
Pupae	—	42	42	—	100.0	100
Microlepidoptera	—	1	1	—	100.0	100
Total insects	476	466	942	50.5	49.5	100
Myriapoda	14	22	36	38.9	61.1	100
Spiders	10	22	32	31.3	68.7	100
Oribatei:						
Phthiracaridae	4	36	40	10.0	90.0	100
Lohmanniidae	50	10	60	83.3	16.7	100
Epilohmanniidae	6	5	11	54.5	45.5	100
Eremaeidae	18	12	30	60.0	40.0	100
Pterogasterina	22	16	38	57.8	42.2	100
Other Sarcoptiformes:						
Rhizoglyphus	12	6	18	66.7	33.3	100
Trombidiformes :						
Nanorchestidae	50	2	52	96.2	3.8	100
Other Trombids	34	6	40	85.0	15.0	100
Mesostigmata :						
Gamasides	14	7	21	66.7	33.3	100
Total mites	210	100	310	67.7	32.3	100
Total arthropod fauna	710	610	1320	53.8	46.2	100

respectively 15.55, 5.04, and 3.78% of the total insects. This phenomenon was also right in the case of the flotation method, with the exception of Thysanoptera, as these three orders constructed 12.88, 4.94, and 6.87% of the total insect fauna, respectively. Though four specimens of Thysanoptera were extracted from 20 samples by the TULLGREN-funnel, yet 104 specimens of this order were extracted by the flotation method from the same number of samples. This high count was possibly due to dead specimens fallen from the onion plants and extracted by the latter method.

In the case of Diptera, the number of flies obtained by the TULLGREN-funnel was so great (74 flies) as compared with the number obtained by the flotation method (12 flies). This was possibly due to the attraction of such flies by the light on the TULLGREN-funnel. The high count of the hymenopterous specimens in the case of the flotation method was also due to masses of pupae gathered together and could not be extracted by the other method.

As to mites, *Oribatei* constructed a large fraction of the soil mite fauna, reaching 50.6% of the total mites in the case of the TULLGREN-funnel method and 79% in the case of the flotation method. With the exception of the Phthiracaridids, the superiority of the former method over the latter in extracting all mite groups was very apparent.

The comparison between the two methods of extraction adopted was already mentioned. But in order to give a better conception about their extraction effeciency Table VI has been constructed. The percentages are given with the supposition that the whole number obtained by the two methods for any group of fauna is 100 specimens. From that Table, it could be remarked that the TULLGREN-funnel methodwas more effective for the extraction of *Collembola*, adult *Diptera* (?), *Psocoptera*, and all mite groups other than Phthiracaridids. The flotation method was more suitable for extracting *Thysanura*, adult *Coleoptera*, *Myriapoda* (Symphalids), spiders and Phthiracardid mites. The efficiency of the two methods in the case of arthropod fauna of a fallow land was also illustrated by the writer (1957).

V. SUMMARY

1. — No members of *Onychophora* or *Crustacea* were met with.

2. — Millions of other Arthropods per acre were existing. Insecta exceeded mites in number and the two composed a very large fraction of the total Arthropod fauna. Percentages of Myriapoda and spiders were relatively very low.

3. — Means per acre for the Arthropod groups obtained were given.

4. — Comparison between the TULLGREN-funnel method and the flotation method was discussed and the efficiency of the two methods was illustrated.

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STUDIES ON THE SUSCEPTIBILITY OF DIFFERENT STAGES OF THE COTTON LEAF-WORM, *PRODENIA LITURA* F., TO CERTAIN CHLORINATED COMPOUNDS

[with 22 Text-Figures and 4 Tables]

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INTRODUCTION

It is known that the susceptibility of an insect to any given poison varies widely with its stage of development, where the criterion of toxicity is the concentration of poison required to kill a given number of individuals. With any given species, large variations in susceptibility may occur throughout the life-cycle and it would seem important for the purposes of practical control that some knowledge is available on the changes of resistance with the stage of development, both in order to assist the correct timing of the application of the insecticides and their efficiency in practical control..

The chemical control of *Prodenia litura* F. in Egypt has passed through a long series of trials. The first attempt was the use of arsenical compounds specially calsium arsenate in a mixture form with lime and sulphur in equal parts by weight dusting or spraying on plants. In fact it gave good results but the drawback was that it affected the plants and was followed by an infestation of aphids. The following trials were the use of chlorinated compounds and the most promising of this group was the so called cotton dust 3:10:40 (γ-BHC, DDT and sulphur respectively) and Toxaphene emulsifiable containing 50% by weight.

Concerning the susceptibility of the different stages of *Prodenia litura* F. to chlorinated hydrocarbons, no work has been carried out specially under uniform conditions in the laboratory.

The present investigation was carried out to obtain a complete data with the idea of claryfying the effect of DDT, γ-BHC and Toxaphene as solutions on the different instars of the cotton leaf-worm and having a statistical account concerning the lethal doses of these insecticides and the proper timing of the practical chemical control.

MATERIALS AND METHODS

Breeding technique

Cotton plants growing in a certain plot were checked daily until the moths deposited their eggs. The egg-masses were labelled and marked by a plate showing the date of depositing and the number of masses per leaf. By this means, eggs of different ages were available for studying the ovicidal effect of the insecticides used.

When the eggs showed black spots, the masses were collected by hand and placed in Petri dishes over fresh cotton leaves. The Petri dishes were covered with moslin cloth and kept in a cage in which continuously wet cotton pads were put to produce suitable humidity for hatching. The eggs were checked twice daily until hatching occured.

The larvae were transfered after hatching to different Petri dishes with the idea of obtaining the 1st and 2nd larval instars. After five days from hatching, the larvae were sufficiently large to handle and easily removed to rearing cages supplied with stripes of cotton leaves and humidity sources. The rearing cages were kept in the laboratory at room temperature to obtain the different larval instars for the investigation.

Insecticides used

The following insecticides were used: (1) DDT: 2 2 bis (parachlorophenyl) 1. 1, 1 trichlorocthane (m.p. 108°); (2) BHC: pure 1, 2, 3, 4, 5, 6 hexachlorocyclohexane 99% gamma isomer (m.p. 112°); (3) technical chlorinated camphene 100% with chlorine content from 67-69% (m.p.68°).

Spraying technique

Tattersfield and Potter's (1943) method of direct spraying was employed throughout the experiments. The eggs and the different larval instars were treated in a spraying apparatus (Potter, 1952) which is designed to give an even deposit over the sprayed area and provide a wide range of reproducible deposits of 9 cm. diameter. The apparatus consists of a reservoir and a specially designed atomizing nozzle mounted on a small circular plate carried on three bars at an angle of 120° with the other. The end of each bar rests on the top flange of the spraying tower by brass terminals of the type containing eye-holes to permit adjustment of the direction of the atomized jet down the spray tower. The spray tower is a metallic

tube of a cone shaped upper portion with a length of 13 1/2 inches with diameter at top 6 3/4 inches tapering to 4 3/4 inches bore. The spray solution passes along the spray tower to a circular spray table which has arrangments for levelling, centring and adjusting the gap between the table and the bottom of the spray tower. The apparatus used is shown in Figure 1.

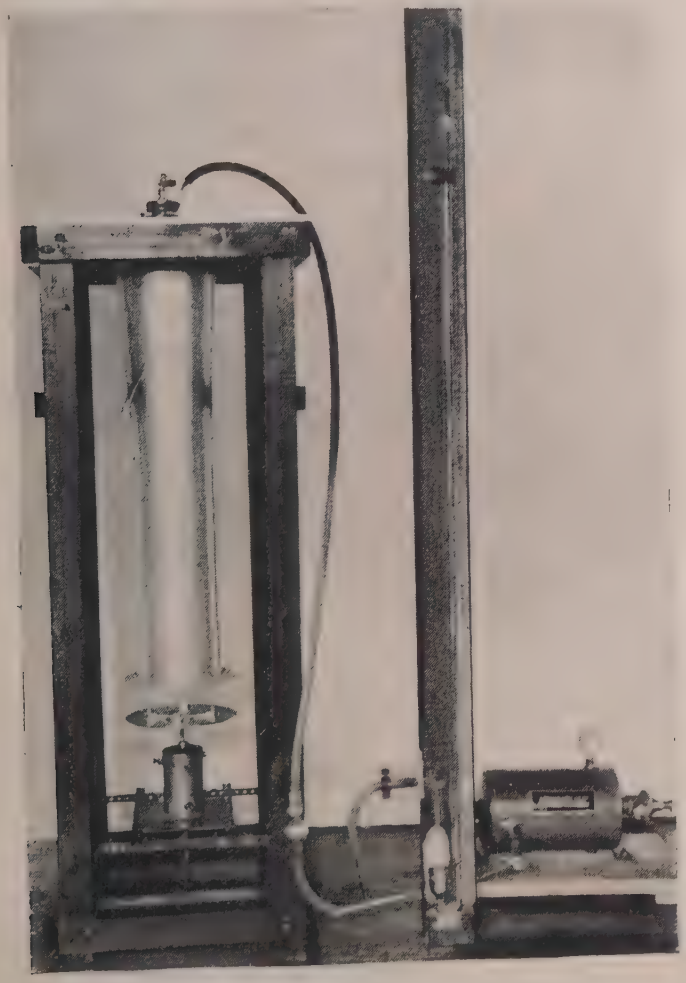


FIG. 1 : POTTER spraying apparatus.

The test insects were confined in a Petri dish of 9 cm. diameter containing a filter paper and then sprayed directly with 2 cc. of liquid insecticide in acetone.

Sprays of different strengths were made by altering the concentration of the insecticide in acetone but the volume of the liquid and the area of the sprayed surface were kept constant. The spraying conditions in the laboratory were uncontroled, i.e. the relative humidity and temperature.

Biological methods were used throughout the investigation where the treated larvae were classified into dead and alive individuals and the assessiment of the effect was made 24 hours after spraying with the insecticidal solutions.

RESULTS

Relative resistance of different stages to DDT, γ-BHC and Toxaphene.

Eggs

Eggs of different ages were separated individually by a paint brush soaked in water. 100 eggs from each age were placed on a filter paper fitted in a Petri dish and treated with the direct spray method. Three replicates were carried out for each concentration for each age group. The treated eggs were inspected as soon as the control which had been sprayed with acetone only had hatched and the larvae had completely freed themselves from the chorion.

It was observed in this set of experiments that with all concentrations of insecticides used and with different age groups no effect on the embryonic development occured as evidenced by the time of hatching of both treated and untreated eggs of the same age. Death only occured when the larvae started moving on the treated surface.

Larval instars

The age of larvae is indicated in terms of instars of which there are six. In addition to age, the individual average weight of the larvae at each particular instar was obtained. After spraying, the Petri dishes were covered with a moslin top held in place by a rubber band and kept in the laboratory at room temperature. The insects were provided with fresh food daily.

Data obtained in this part were analysed by the standard method of probits and dosages (FINNEY, 1947). The medium lethal concentration (M.L.C.) of each insecticide for each age group was obtained from the regression equation. The relative resistance of each age group was calculated from the M.L.C. by assigning an arbitrary value of 1.0 as the resistance of the youngest age group.

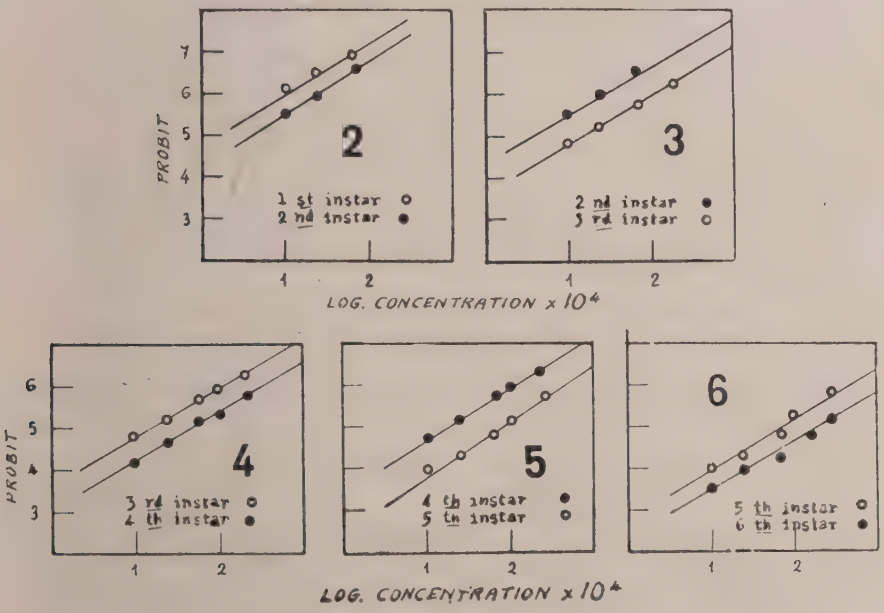
The analysed results are given in Tables I, II and III, and the concentration mortality regression lines are shown in Figures 2-22.

From these Tables, it can be seen that the resistance of different instars to the insecticidal solutions used increased consistantly as the development proceeded. Each successive instar was more resistant to the insecticide.

TABLE I

Effect of difference in larval instars of Prodenia litura *on their resistance to* 1: DDT.

Instars	Weight (mg.)			Medium lethal concentration percentage W/V	Relative resistance
	Maximum	Minimum	Average		
1st.	0.27	0.12	0.20	0.004	1.0
2nd.	5.00	2.80	4.40	0.006	1.5
3rd.	48.00	25.00	39.00	0.012	3.0
4th.	195.00	125.00	164.00	0.025	6.2
5th.	642.00	435.00	514.00	0.075	18.8
6th.	900.00	635.00	809.00	0.120	30.0



FIGS. 2-6 : Probit mortality log. concentration of poison showing the effect of difference in larva Instars on their susceptibility to DDT.

DISCUSSION

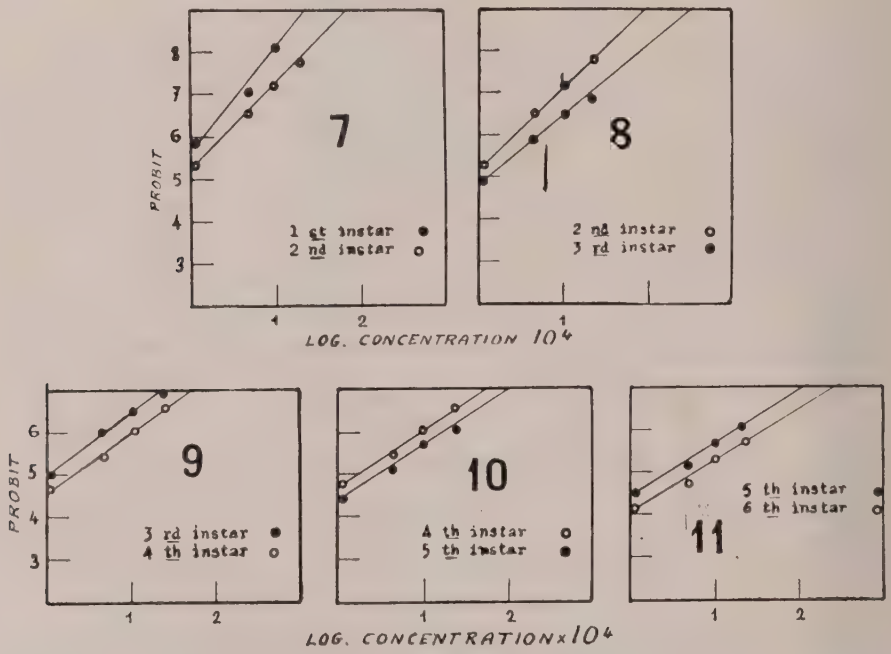
The experiments considered in a part of this investigation have led to the fact that no difference in susceptibility with age of the eggs was noticed when the insecticidal solutions were applied to egg batches. All eggs of different age groups treated with different concentrations hatched in approximate time with the control which

TABLE II

11 : γ - BHC

Effect of difference in larval instars of Prodenia litura *on their resistance to* 11: γ - BHC.

Instars	Weight (mg.)			Medium lethal Concentration percentage W/V	Relative resistance
	Maximum	Minimum	Average		
1st.	0.28	0.19	0.21	0.0003	1.0
2nd.	5.30	2.70	4.25	0.0008	2.7
3rd.	45.00	25.00	38.00	0.0027	9.0
4th.	196.00	127.00	162.00	0.0075	25.0
5th.	650.00	439.00	525.00	0.0090	30.0
6th.	985.00	675.00	823.00	0.0120	40.0



FIGS. 7-11 : Probit mortality log. concentration of poison showing the effect of difference in larval instars on their susceptibility to BHC.

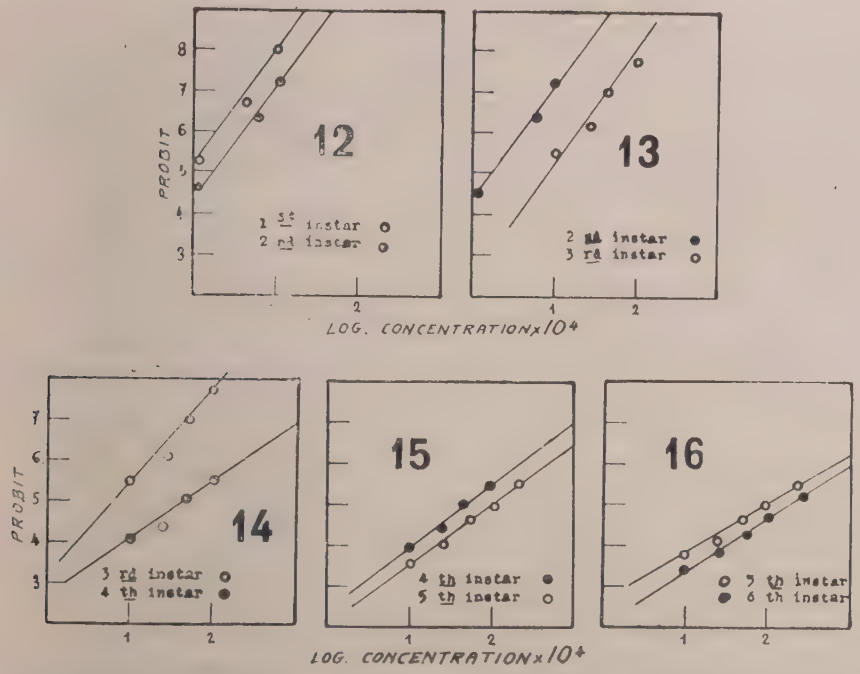
was sprayed with acetone only. This means that DDT, γ-BHC and Toxaphene even at highest concentrations failed to prevent hatching and death only occured after fully developed embryo had started moving over the treated surfaces.

Concerning the larval instars, experiments described in, showed the concentration-mortality relationship with different instars for DDT, γ-BHC and Toxaphene.

TABLE III

Effect of difference in larval instars of Prodenia litura *on their resistance to 111*: Toxaphene

Instars	Weight (mg.)			Medium lethal concentration percentage W/V.	Relative resistance
	Maxinum	Minimum	Average		
1 st	0.27	0.12	0.20	0 002	1.0
2 nd	5.00	3.60	4.30	0 004	2.0
3 rd	48.00	25.00	39.00	0.009	4.5
4 th	195.00	125.00	164.00	0.050	25.0
5 th	642.00	435.00	514.00	0.100	50.0
6 th	900.00	635.00	809.00	0.150	75.0



FIGS. 12-16 : Probit mortality log. concentration of poison showing the effect of difference in larval instars on their susceptibility to Toxaphene.

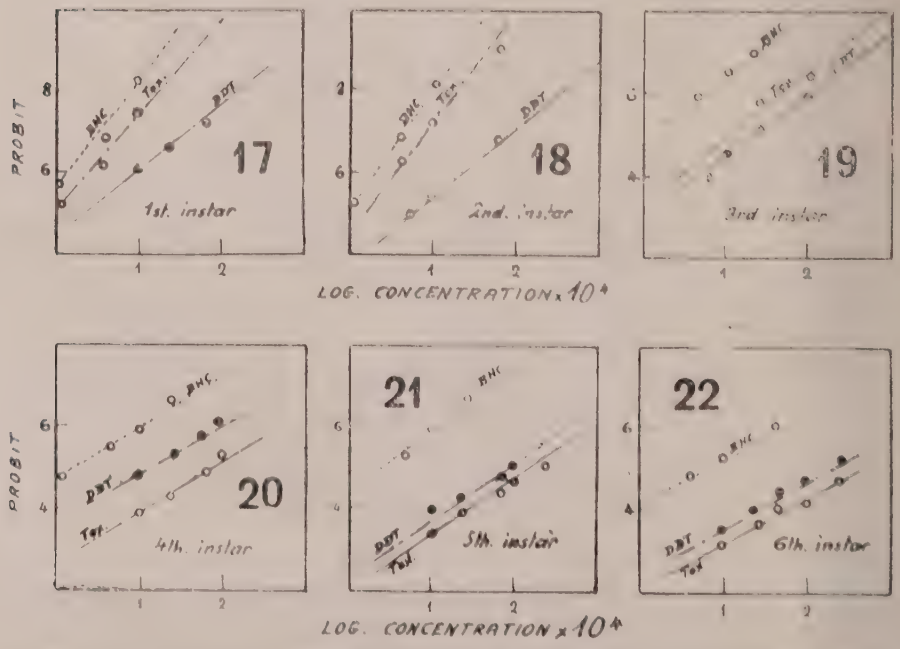
The assessiment of the effect was carried out 24 hours after spraying to uniform the period of exposing the larvae to the toxic materials. The results obtained were translated to probit log. concentrations and ploted in Figures 2-22 to illustrate the relative susceptibility of the larval instars to the insecticides used.

In the case of DDT there was no significant deviation from parallism between any of the lines (Figs. 2-6). With γ-BHC a slight deviation from paralellism occured with the comparison between the 1st and the 2nd (Fig. 7) and the 2nd and the 3rd larval instars (Fig. 8).

With Toxaphene, the deviation is significant when comparing the 3rd and the 4th larval instars as shown in Figure 14; otherwise the lines are more or less paralell.

TABLE IV

Stage	Medium lethal concentration			Relative resistance		
	DDT	BHC	Tox.	DDT	BHC	Tox.
1st	0.004	0.0003	0.002	1.0	1.0	1.0
2nd	0.006	0.0008	0.004	1.5	2.7	2.0
3rd	0.012	0.0027	0.009	3.0	9.0	4.5
4th	0.025	0.0075	0.050	6.2	9.0	25.0
5th	0.075	0.0090	0.100	18.8	30.0	50.0
6th	0.120	0.0120	0.150	30.0	40.0	75.0



FIGS. 17-22 : Comparative probit mortality log. concentration poisons showing the effect of DDT, BHC and Toxaphene on the different larval instars of *Prodenia litura* F.

With the three insecticides there has been an increase in resistance with increased larval development.

Table IV gives a clear idea about the relation between the medium lethal concentrations (M.L.C.) and the relative resistances by assigning an arbitrary value of 1.0 as the resistance of the youngest age group.

From Figures 17-22 it can be seen that γ-BHC is more effective for the six larval instars. Toxaphene comes in the second position after γ-BHC till the third stage and is replaced by DDT in the 4th, 5th and 6th stages That means that Toxaphene is less toxic to the advanced stages a fact which should be considered in choosing the proper time of applying the toxic material.

SUMMARY

1. — DDT, γ-BHC and Toxaphene as chemically pure materials were used in the investigation in different concentrations in spray form with the aid of Potter tower following the technique of the direct spray method.

2. – A discription of the breeding technique and the assessiment of the effect is given also a brief idea about the spraying device used in the study is mentioned.

3. – The results obtained in a part of the study showed that the insecticides had no effect on the eggs of the cotton leaf-worm even when high concentrations were used. The check of the treated eggs were done when the control hatched.

4. — With the larval instars, the results were translated in probit log. concentrations and plotted in Figures to illustrate the relative resistance of the different age stages to the insecticides used. The relation between the M.L.C. and the relative resistants are summarized in a separate table with the disscussion. The resistance increased consistently with age.

5. — From a comparison of the probit log. concentration poisons (Figs. 17-22) the order of efficiency of the toxic materials used was as follows: for the 1st, 2nd and 3rd instars: γ-BHC, Toxaphene, DDT; for the 4th, 5th and 6th instars: γ-BHC, DDT, Toxaphene.

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ECOLOGICAL STUDIES ON THE ENVIRONMENT PREFERENCE AND SEX-RATIO IN CATCHES OF MACRO-LEPIDOPTERA IN ULTRA-VIOLET LIGHT TRAPS

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These studies were carried out at Rothamsted Experimental Station, Harpenden (25 miles north of London). Nocturnal Macro-lepidoptera were sampled between sunset and sunrise each night for two complete years by means of two Robinson mercury vapour light traps. These were situated in two different localities though close to each other; one in the open and the other inside a thick woodland (about 14 acres altogether). A total of 36.144 moths was caught during these two years in the trap out in the open (Trap G) and 22.773 moths inside the wood (Trap F). A complete list of both the numbers and the species caught has been published elsewhere (HOSNY, 1953).

The daily catches were sorted out into families and species, sexed, counted, recorded and preserved for any further examination.

I. ENVIRONMENT PREFERENCE OF MACRO-LEPIDOPTERA IN TWO TRAPPING LOCALITIES

Distribution of catches in the traps

The numbers of the daily catches were transformed into their logarithms to facilitate their graphical illustration and to smooth down the frequency distribution curve of the data (WILLIAMS, 1937). The form log. (n + 1) was used to avoid complications caused by the presence of zero catches. In this way the daily catches are shown graphically in Figure 1. Each bar in this figure illustrates the daily degree

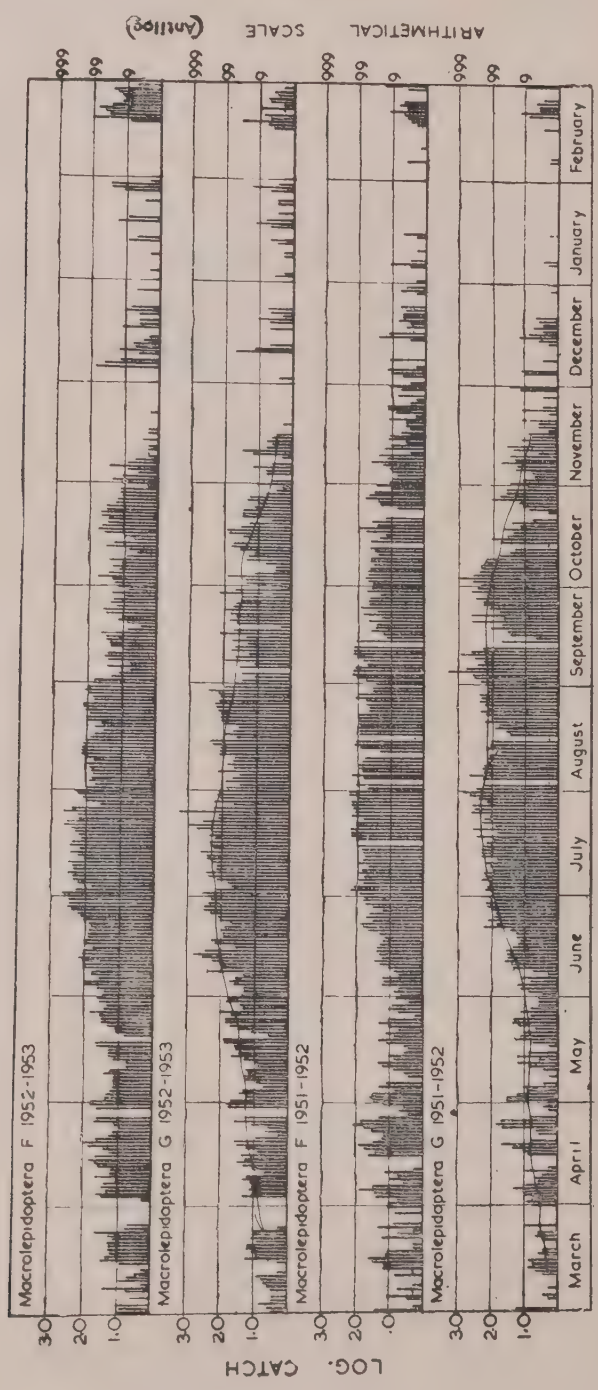

FIG 1 : Daily log. catch of Macro-lepidoptera in two trapping localities.

of activity within the group as indicated by the log. catch. It may be noticed from this that the fluctuations in the catch inside the wood were less conspicuous than the corresponding ones in the open. This is very likely due to the effect of trees in damping down the micro-climatic changes as compared with outside.

The daily log. catches in the open (Trap G) were corrected from March to November for the average monthly effect of the three main weather factors, mean-night, day-maximum temperatures and night wind velocity as indicated by the partial regressions on these factors. A 29-day running mean of these corrected values was then calculated and by this procedure most of the effect of other secondary factors such as moonlight, rainfall, etc., on these catch figures is believed to have been smoothed out. The calculated 29-day running mean values are superimposed on the two graphs for the catches in Trap G between March and November (irregular horizontal line). Fluctuations in this line are, therefore, the nearest possible indicators of fluctuations in the population level of Macro-lepidoptera, the relation of which to the catch and various components of preceding and prevailing environmental conditions could be determined. A study of this in the two years shows in 1951 a steadily increasing population during March, April and May, rising with a comparative rapidity in June to reach a peak by the end of July. Throughout August and September a steady level was maintained at nearly the same height as the average for July. In October and November a fairly rapid decline took place. In 1952 in the months of March to June inclusive the population level was generally higher than that of the corresponding period in 1951, increasing almost gradually throughout this period. A peak was reached in July, similar in height to that of July 1951, after which a gradual decline occurred in the following four months. A noticeable steadiness has been maintained during the second half of September and the first half of October. Generally the population level in the last four months after July 1952 was well below that of the corresponding period in 1951.

Abundance of families in the catches

The monthly total catch of Macro-lepidoptera and that of Geometridae, Noctuidae and "other families" in the traps during the two years, indicated a general tendency in the catches of Geometridae and Noctuidae to maintain somewhat similar proportions of the total catch in each trap for similar months. This may be more obviously illustrated by the seasonal values given in Table I.

These percentages are shown graphically in Figure 2, together with the seasonal number of species (Table II) in each case to give an idea of the corresponding abundance of species. It is obvious from this, that the changes in the percentages were independent from those in the number of species.

It may be noticed also that the Geometridae were always more abundant, both in percentage and in number of species, inside the woodland than in the open; for Noctuidae the reverse and for "other families" there was no apparent distinction.

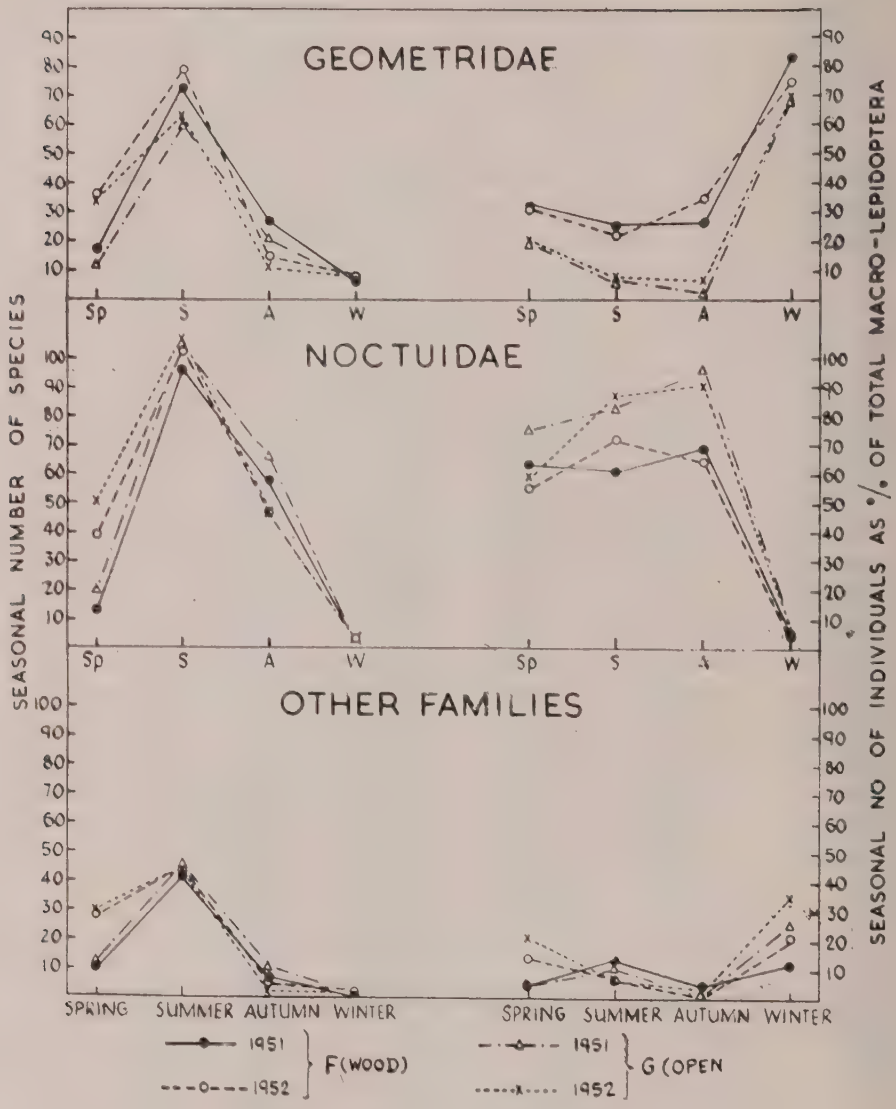

FIG. 2 : Seasonal changes in the percentages.

The seasonal changes in the percentages of Geometridae and Noctuidae, as shown in Figure 2, followed more or less similar patterns both in the same locality during the two years and in the two localities in the same year. The "other families" showed only the latter.

TABLE I

Seasonal percentage of families in the catches.

Family	Trap	Year	Spring	Summer	Autumn	Winter*	Whole year
Geometridae	Woodland	1951	32 5	25 5	26 5	82 5	27.5
		1952	31.0	22 0	35 0	74.5	26.0
	Open	1951	20 0	6 5	2 5	68.5	5.0
		1952	21.0	7 0	7.0	70.0	8.5
Noctuidae	Woodland	1951	63.0	61.0	69.0	5 5	62.5
		1952	55.0	71.5	64.0	4 5	66.5
	Open	1951	75.5	83.0	96.0	6.5	88.5
		1952	58.5	87.0	90.5	4.5	84.5
Other families	Woodland	1951	4.5	13.5	4 5	12.0	10.0
		1952	14.5	6.5	1.0	21.0	7.5
	Open	1951	4.5	10.5	1.5	25.0	6.5
		1952	0.52	6.0	2.5	34.5	7.0

(*) The winter months are December of the same year, January and February of the following one.

The catches in both localities during the winter were mainly Geometridae (8 species altogether), with a minority of Noctuidae (3 species) and "other families" (2 species); the latter group being more abundant in numbers than Noctuidae but this was mainly due to one species (*P. populi*).

TABLE II

Seasonal number of species in the catches.

Family	Trap	Year	Spring	Summer	Autumn	Winter
Geometridae	Woodland	1951	17	73	27	7
		1952	36	79	15	8
	Open	1951	12	60	21	7
		1952	34	63	16	7
Noctuidae	Woodland	1951	13	96	58	2
		1952	39	102	47	3
	Open	1951	20	105	66	2
		1952	50	106	47	3
Other families	Woodland	1951	10	41	7	1
		1952	28	43	5	2
	Open	1951	12	45	10	1
		1952	29	43	2	1

Environment preference of species in the two localities

To extend this analysis further to the species belonging to each of the three above-mentioned groups of Macro-lepidoptera, Figures 3, 4 and 5 were constructed. They illustrate the number of individuals per species caught in two years in each locality plotted one against the other. The percentage of the total occurrence for

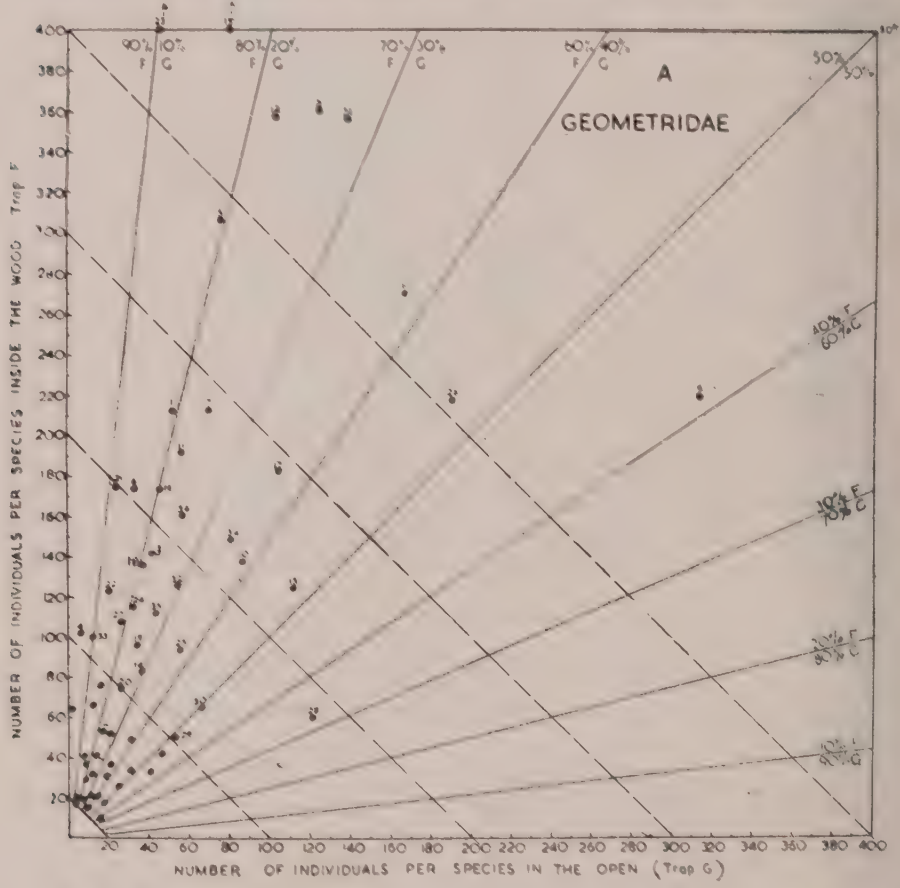
A
GEOMETRIDAE
90% F 10% G
80% F 20% G
70% F 30% G
60% F 40% G
50% 50%
40% F 60% G
30% F 70% G
10% F 90% G
NUMBER OF INDIVIDUALS PER SPECIES INSIDE THE WOOD Trap F
NUMBER OF INDIVIDUALS PER SPECIES IN THE OPEN (Trap G)
20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 380 400

FIG. 3 : Total numbers caught and percentages of occurrence of different species of "Geometridae" in the two trapping localities in two years (References to numbered species are given in Table III).

each site in indicated by the lines radiating from the base of the graph. The broken lines indicate the total numbers of each species obtained from both traps. The data used are the numbers of individuals caught in the two traps with the exclusion of species with a total catch of less than 20 individuals during the two years. All species

with a total catch of over 100 individuals are numbered on the Figures and a reference is given to each of them in Tables III, IV and V. Species with a total of over 400 individuals had to be plotted on the edges of the graph with respect to the percentage of occurrence. As catches inside the woodland are drawn from a more restricted

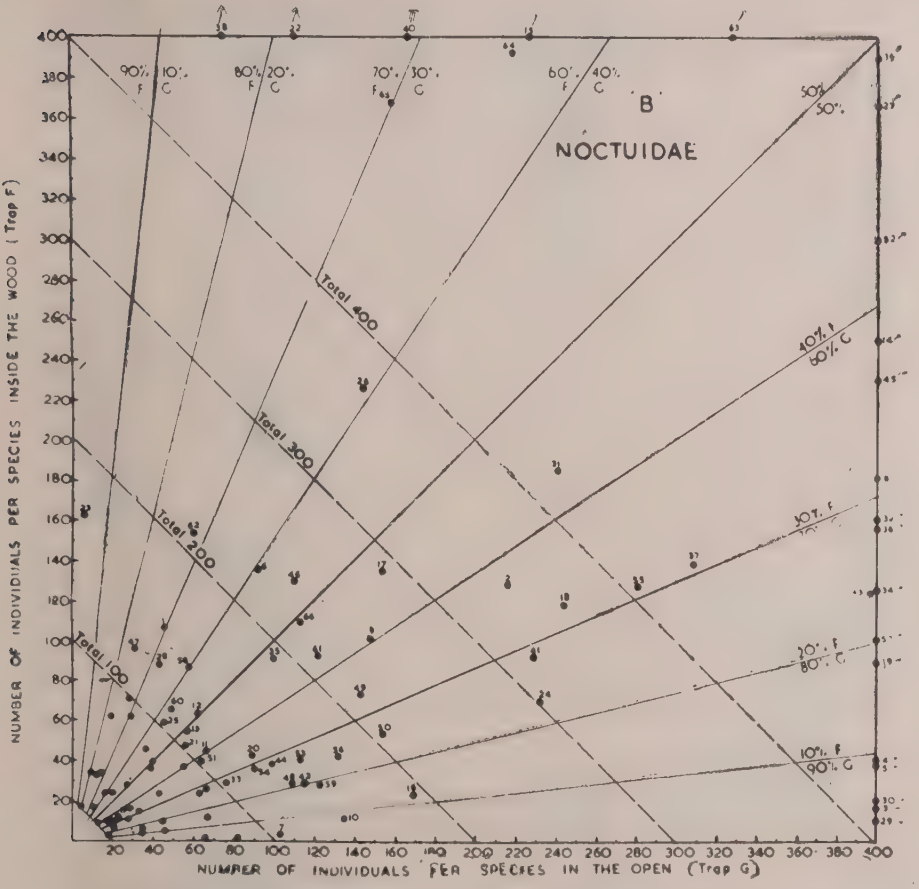

FIG. 4 : Total numbers caught and percentages of occurrence of different species of "Noctuidae" in the two trapping localities in two years (References to numbered species are given in Table IV).

area, a limit of over 70% of the individuals inside the wood was considered as an indicator of a "woodland" species, but 80% was taken as the limit of an "open country" species. It was therefore possible to get an idea about the fairly common species of Macro-lepidoptera that may be called woodland or open country (grassland) species with a certain degree of reliability.

It is evident from Figure 3 that most of the Geometrid species occurred in higher proportions inside the woodland; the Noctuidee (Fig. 4) showed a tendency to be more abundant in the open; whereas species of "other families" were more or less evenly distributed in the centre of Figure 5.

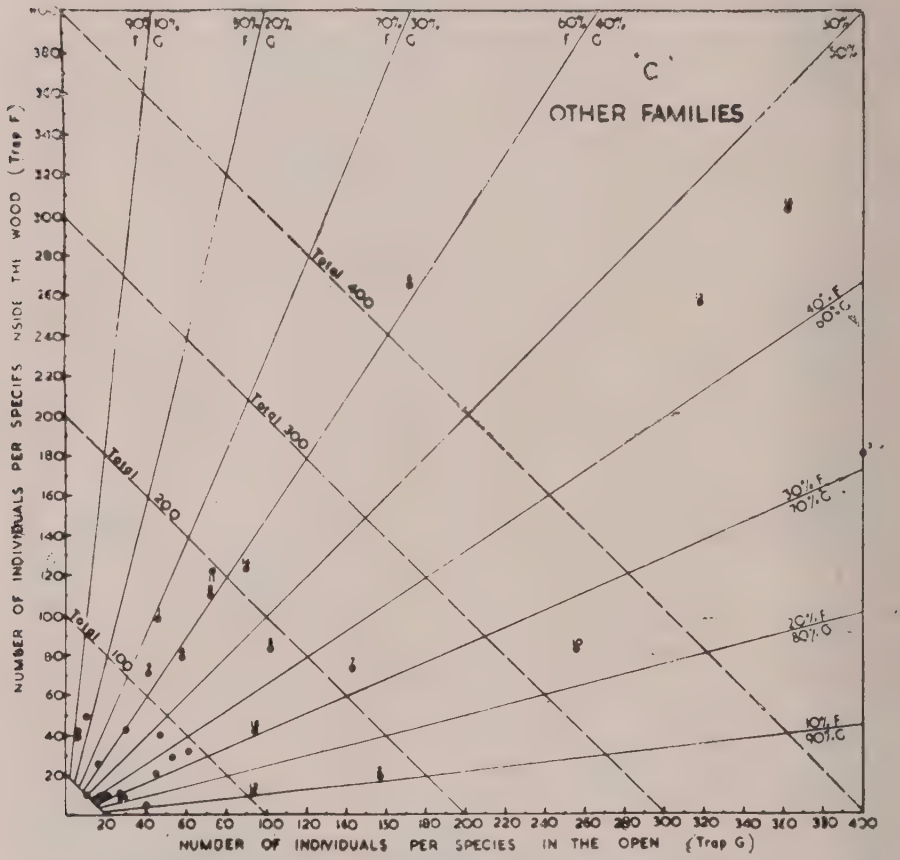
'C'
OTHER FAMILIES
90% F / 10% G
80% F / 20% G
70% F / 30% G
60% F / 40% G
50% F / 50% G
Total 400
Total 300
Total 200
Total 100
40% F / 60% G
30% F / 70% G
20% F / 80% G
10% F / 90% G
NUMBER OF INDIVIDUALS PER SPECIES INSIDE THE WOOD (Trap F)
NUMBER OF INDIVIDUALS PER SPECIES IN THE OPEN (Trap G)
20 40 60 80 100 120 140 150 180 200 220 240 260 280 300 320 340 360 400

FIG. 5 : Total numbers caught and percentages of occurrence of different species of "other Families" in the two trapping localities in two years (References to numbered species are given in Table V).

None of the Geometrid species occurred with over 80% of its total in the open, whereas over 70% of the total in 25 species was caught inside the wood (underlined figures in Table III). These, accordingly, may be considered woodland species.

In the Noctuidae, according to Figure 4 and Table IV, *C. coryli*, *D. primulae*, *Z. griseatis*, *H. proboscidalis*, *C. trapezina*, *C. graminis*, *C . vaccinii*, and *O. cruda*

TABLE III

Abundance of species of Geometridae with over 100 individuals in the two light traps, F (inside the woodland) and G (in the open). Numbers in italics indicate species with over 70% of their total catch in Trap F (woodland).

Species	F	G	Total	Species	F	G	Total
S. bilunaria	*213*	51	264	*H. aestivaria*	*96*	34	130
L. hirtaria	*361*	124	485	*L. associata*	*74*	26	100
S. tetralunaria	*142*	183	183	*O. sambucaria*	*175*	24	199
E. bistortata.....	*102*	108	108	*E. sociata*.....	*123*	20	143
X. ferrugata	*307*	75	382	*O. dilutata*	*470*	63	533
E. silaceata	*174*	33	207	*P. alchemillata*.....	*115*	32	147
X. spadicearia	*213*	69	282	*H. furcata*	94	55	149
O. luteolata	271	166	437	*D. erosearia*	218	190	408
B. betularia	220	313	533	*A. grossulariata* ...	*108*	26	134
T. obeliscata	138	86	224	*D. fuscantaria*	60	121	181
D. truncata	*192*	56	248	*E. quercinaria*	50	53	103
C. amata	*358*	102	460	*C. pennaria*	65	66	131
Eupithecia sp.	125	111	236	*A. aescularia*	*357*	138	495
X. montanata	*83*	36	119	*P. pedaria*.....	*126*	54	180
C. margaritata ...	*472*	96	568	*E. leucophaeria* ...	*100*	12	112
A. repandata	*174*	45	219	*B. strataria*.....	149	80	229
A. genmaria	183	104	287	*O. brumata*	*112*	43	155
S. aversata	*136*	37	173	*N. defoliaria*	*161*	56	217

may be considered woodland species. On the other hand, *P. meticulosa*, *P. gamma*, *A. monoglypha*, *A. ypsilon*, *C. pisi*, *A. basilinea*, *L. comma*, *A. c-nigrum*, *A. anceps*, *A. lychnidis* and *A. macilenta* may be considered grassland or open country species. WILLIAMS et al. (1942) produced considerable evidence that the first three species might be migrants. The fourth (*A. ypsilon*) is, of course, a well known migrant in many parts of the world.

As for species in "other families" (Fig. 5 and Table V), only *P. tremula* and *M. neustria* show a tendency to be open-country species. The latter, according to WILLIAMS et al. (1942) was recorded once at a light-ship (10 m. south-east of Felixstowe, S. Suffolk).

II. SEX-RATIO IN THE CATCH

The percentage of females

It is commonly known that in most of the non-parthenogentic insects, equal numbers of males and females are produced and this is usually used in computing possible multiplication and consequent damage. It was, therefore, thought desirable to present some evidence on this point, as indicated by the catches of Macro-lepidoptera in the two light traps. It was for this reason that sex records have been kept of every moth collected in the traps.

TABLE IV

Abundance of species of Noctuidae with over 100 individuals in the two light traps, F (inside the woodland) and G (in the open).

Numbers in italics indicate species with either over 70% of their total catch in Trap F (woodland) or over 80% in Trap G (open country).

Species	F	G	Total	Species	F	G	Total
C. coryli	*106*	46	152	*L. pallens*	235	770	1005
D. oleracea	128	216	344	*P. jota*	92	100	192
P. meticulosa	44	*1056*	1100	*A. secalis*	1327	3332	4659
P. gamma	42	*409*	451	*L. lithargyria*	138	309	447
A. ypsilon	51	*578*	629	*H. proboscidalis*	*417*	79	496
A. rumicis	136	92	228	*L. impura*	520	529	1049
C. pisi	4	*103*	107	*C. trapezina*	*1165*	501	1664
A. exclamationis	2169	4897	7066	*L. conigera*	92	229	321
A. segetum	102	148	250	*L. fimbriata*	29	115	144
A. basilinea	12	*135*	147	*T. comes*	124	398	522
H. lepida	45	66	111	*A. pyramidea*	39	99	138
H. dentina	64	62	126	*T. janthina*	287	499	786
A. tripartita	55	57	112	*H. coulea*	130	110	240
C. plecta	375	582	957	*C. graminis*	*96*	31	127
M. trigrammica	569	339	908	*A. tragopoginis*	29	109	138
L. comma	24	*169*	193	*A. sexstrigata*	74	143	217
A. putris	135	154	289	*L. testacea*	54	154	208
D. rubi	118	244	362	*T. cespitis*	40	64	104
A. c-nigrum	1668	*7853*	9521	*A. xanthographa*	308	420	728
H. reticulata	43	89	132	*H. micacea*	41	113	154
A. psi	48	56	104	*T. popularis*	36	90	126
D. primulae	*540*	157	697	*C. lunosa*	127	281	408
Z. grisealis	*163*	6	169	*A. litura*	43	132	175
P. latruncula	70	232	302	*A. lychnidis*	556	*2198*	2754
C. rubricosa	59	45	104	*A. circellaris*	87	58	145
R. tenebrosa	226	144	370	*A. macilenta*	29	*123*	152
Caradrina sp.	1032	1130	2162	*A. oxyacathae*	66	49	115
E. lucipara	88	43	131	*B. sphinx*	93	122	215
A. anceps	24	*966*	990	*C. vaccinii*	*154*	60	214
A. monoglypha	147	*2740*	2887	*O. gothica*	641	514	1155
P. chrysitis	185	241	426	*O. stabilis*	392	219	611
T. pronuba	1666	4018	5684	*O. cruda*	*367*	159	526
P. nitens	29	76	105	*O. incerta*	110	113	223

The figures in Tables VI and VII show the seasonal (catch of both males and females of "all Macro-lepidoptera", of "Geometridae", of "Noctuidae" and of "other families" together with the percentages of females in the total in each case. It is evident from these tables that there is a decided preponderance of males in the catch and that some constancy in the results could be traced as may be seen in Figure 6. The graph for "all Macro-lepidoptera" in the figure indicates, more or less, similar

TABLE V

Abundance of species of "other families" with over 100 individuals in the two light traps, F (inside the woodland) and G (in the open).

Numbers in italics indicate species with over 80% of their total catch in Trap G (open country).

Species	F	G	Total
D. ruficornis	98	46	144
P. tremula	19	*157*	176
S. lubricipeda	236	474	710
L. camelina	79	58	137
L. populi	83	102	185
S. lutea	172	172	437
P. bucephala	73	143	216
D. binaria	110	72	182
H. velleda	71	41	112
H. pyritoides	82	256	338
P. potatoria	122	73	195
M. neustria	11	*93*	104
E. lurideola	256	318	574
E. similis	123	90	213
A. caja	42	94	136
P. populi	302	352	654

fluctuations in the seasonal percentages of females between the two traps in each year but not between the two years. The percentages were round the 20-30% level on average during the spring, summer and autumn but dropped considerably during the winter months. This is mainly due to the fact that during the latter season the Geometridae dominate the catch of Macro-lepidoptera in both traps and all the 8 Geometrid species caught at that time of the year had wingless females.

The whole year percentages in Tables VI and VII showed a clearer constancy (with a difference of about 3% or less) both between years and localities in the case of "all Macro-lepidoptera" and Noctuidae. For Geometridae, Trap G showed closer results in the two years (14.5% and 16%) which were also close to that obtained in Trap F during 1951 (17%).

For "other families", Trap F showed close percentages in the two years (15.5 and 18%) and these were similar in magnitude to that shown by the catches in Trap G in 1952 (15.5%).

The general preponderance of males in the catches may be due to the fact that the males usually search for females and are thus more active and so more likely to be caught in greater proportion.

The effect of weather factors on both sexes

In an attempt to test whether there is a difference in the effect of the main weather factors on the activity of both males and females, the catches of Noctuidae

TABLE VI

Seasonal sex proportion in catches of Macro-lepidoptera (Trap F, inside the wood).

Season	Year	Total Macro-lepidoptera			Geometridae			Noctuidae			Other families		
		Males	Females	Females %	Males	Females	Females %	Males	Females	Females %	Males	Females	Females %
Spring (March-May)	1951	1150	274	19.0	460	5	1.0	638	262	29.0	52	7	12.0
	1952	1515	442	22.5	546	57	9.5	745	333	31.0	224	52	19.0
Summer (June-August)	1951	5155	1143	18.0	1254	343	21.5	3190	668	17.5	711	132	15.5
	1952	10740	3617	25.0	2196	954	30.0	7760	2487	24.5	784	176	18.5
Autumn (Sept.-Nov.)	1951	2322	905	28.0	682	172	20.0	1514	711	32.0	126	22	15.5
	1952	1164	276	19.0	470	34	7.0	683	239	26.0	11	3	21.5
Winter (Dec.-Feb.)	1951	196	6	3.0	167	0	0	8	3	27.6	21	3	12.5
	1952	531	24	4.5	388	0	0	22	6	21.5	121	18	15.5
Whole Year (March-Feb.)	1951-2	8823	2328	21 0	2563	520	17.0	5350	1644	23.5	910	164	15.5
	1952-3	4359	4359	24.0	3600	1045	22.5	9210	3065	25.0	1140	249	18.0

TABLE VII

Seasonal sex proportion in catches of Macro-lepidoptera
(Trap G, in the open).

Seasons	Year	Total Macro-lepidoptera			Geometridae			Noctuidae			Other families		
		Males	Females	Females %	Males	Females	Females %	Males	Females	Females %	Males	Females	Females %
Spring (March-May)	1951	557	193	25.5	145	3	2.0	377	190	33.5	35	0	0
	1952	1456	339	19.0	314	63	16.5	811	239	23 0	331	37	10.0
Summer (June-August)	1951	10461	2049	16.5	666	144	18.0	8568	1787	17.0	1227	118	9.0
	1952	13034	4049	31.0	959	207	18.0	11240	3661	24.5	853	181	19.0
Autumn (Sept.-Nov.)	1951	8713	4177	32.5	290	52	15.0	8219	4102	33.5	204	23	10.0
	1952	1600	599	27.0	130	22	14.5	1417	576	29.0	53	1	2.0
Winter (Dec.-Feb.)	1951–2	112	5	4.5	80	0	0	5	4	45.0	28	1	3.5
	1952-3	211	12	5.5	136	0	0	7	3	30.0	68	9	11.5
Whole year (March-Feb.)	1951–2	19843	6424	24.5	1181	199	14.5	17169	6083	26.0	1494	142	8.5
	1952–3	16301	4999	23.5	1539	292	16.0	13475	4179	24.0	1287	228	15.5

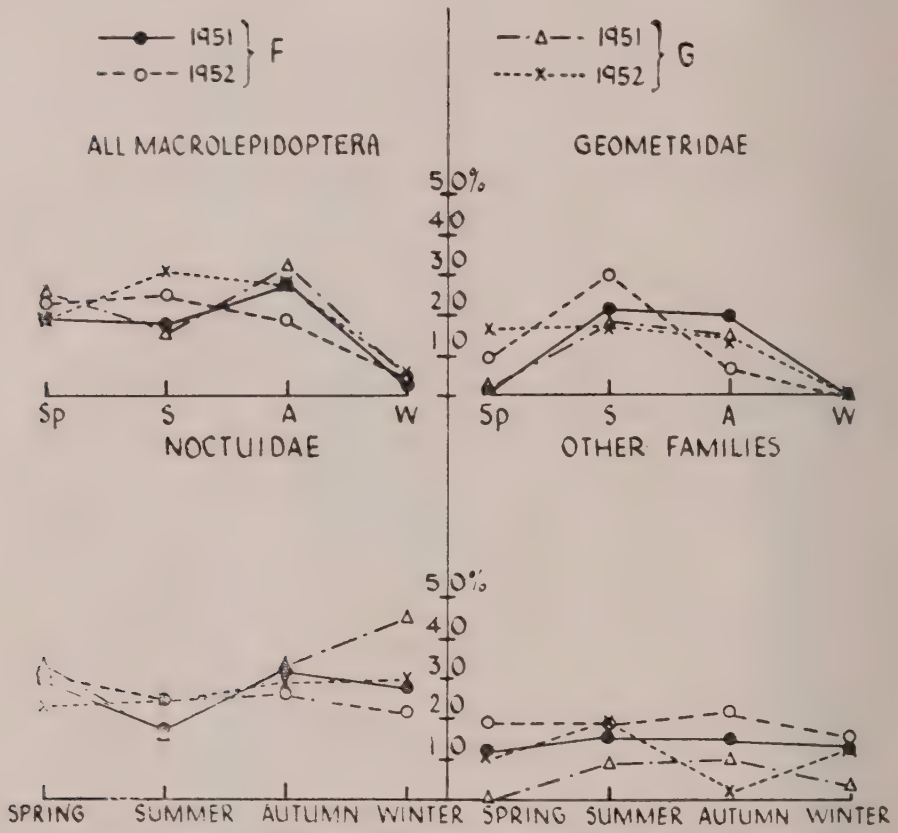

FIG. 6 : The seasonal percentages of females in the catches (Traps F and G).

TABLE VIII

The effect of main weather conditions on the activity of males and females of Noctuidae during July 1951 and 1952 (in italics, regressions are not significant at 5 % level)

Date	Mean-night temp.	Max. temp.	Daily mean temp.	Daily range temp.	Wind velocity	Variance %
July 1951						
Females	+ 0.0843	— 0.0645	+ *0.0094*	— 0.1488	— *0.0475*	40.0
Males	+ 0.0647	— 0.0603	+ *0.0022*	— 0.1250	— *0.0547*	44.0
All Noctuidae	+ 0.0721	— 0.0602	+ *0.0060*	— 0.1323	— *0.0656*	44.0
July 1952						
Females	+ 0.0908	— *0.0078*	+ 0.0415	— 0.0986	— *0.1231*	70.0
Males	+ 0.0558	— *0.0084*	+ 0.0237	— 0.0642	— *0.1818*	60.5
All Noctuidae	+ 0.0648	— *0.0083*	+ 0.0283	— 0.0731	— 0.1678	66.7

in Trap G (in the open) during July of the two years were selected. The daily numbers caught of both sexes were converted into their log. (n + 1) and the partial regression formula was calculated using as data the proportional difference between the log. catch of successive nights.

The percentage of females in the catch of Noctuidae during July was 18.0% in 1951 and 27.5% in 1952. Table VIII gives the partial regression values for males, females and all Noctuidae on the five main weather factors together with the percentage of the total variance explained in each case.

It appears from this table that both sexes of Noctuid moths were affected in almost the same degree by the factors considered in each year.

The percentage of females in relation to the abundance of individuals

WILLIAMS (1939, p. 108) gave evidence of a gradual lowering in the percentage of females with increasing catch of the Noctuid species *A. exclamationis*, *A. lychnidis* and *X. monoglypha* in a light trap.

This point was tested and compared in the present investigation using the values for the same three species in each trap, but no such relation of the percentage of females to the abundance of individuals could be traced.

The figures for the catches of males and females given in Tables VI and VII show a general tendency in the females to increase proportionally to the increase of males in the catch. In an attempt to shed more light on this point the seasonal catches of males and females for "all Macro-lepidoptera" given in Tables VI and VII for both traps were converted into their logarithms to facilitate their graphical illustration. These are given in Table IX and are shown graphically in Figure 7.

TABLE IX

Seasonal log. catch of males and females "all Macro-lepidoptera" in two light traps (actual numbers in Tables II and VII)

Season	Year	Trap F (inside the woodland)		Trap G (in the open)	
		Males	Females	Males	Female
Spring	1951	3.06	2.44	2.75	2.28
	1952	3.18	2.65	3.16	2.53
Summer	1951	3.71	3.06	4.02	3.31
	1952	4.03	3.56	4.11	3.61
Autumn	1951	3.37	2.96	3.94	3.62
	1952	3.07	2.44	3.20	2.78
Winter	1951-2	2.29	0.78	2.05	0.70
	1952-3	2.73	1.38	2.32	1.08

It is obvious from the figure that the differences in the seasonal percentages of males and females in the catch from one year to another in both localities were more or less proportional. This is indicated by the solid and broken lines being approximately parallel to the 50% line.

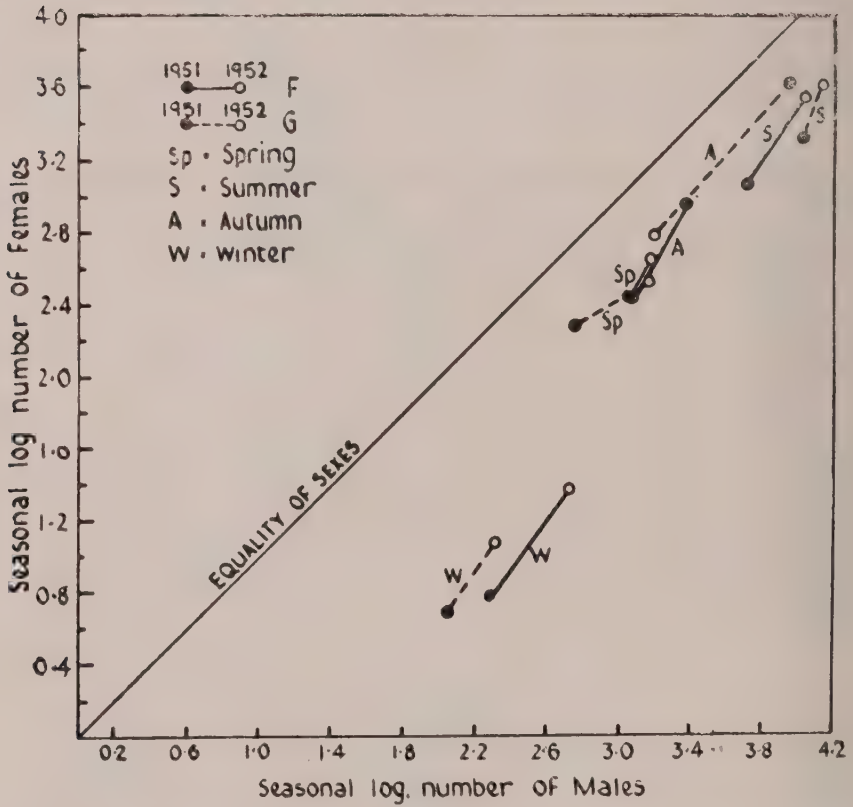

FIG. 7 : The relation between the seasonal percentages of females in the catches of Macrolepidoptera expressed as log. numbers, and the seasonal variations in the size of the catch (Traps F and G in two years).

The explanation of this contradiction between WILLIAMS' and the present results is not quite understood. The difference in the ecological association from which both the old and the present traps drew their catch can hardly be the cause, yet the other conceivable reasons that one can think of may, perhaps, be the use of ultra-violet light in the present studies, or the different structure of the trap.

SUMMARY

Nocturnal Macro-Lepidoptera were sampled, for two years, by means of two ultra-violet light traps situated in two different localities, one in the open and the other inside a thick woodland.

The distribution of Geometridae, Noctuidae and "other families" as individuals and as species in the catches of the two traps shwoed that catches inside the woodland were more stable, or fluctuated less than those in the open.

The fluctuations in the population level of the group has been demonstrated by correcting the daily log. catches for the main weather factors as indicated by their monthly average effect, and then calculating a 29-day running mean of these values in order to smooth out the effect of most of the other environmental conditions.

Geometridae were found to be more abundant inside the woodland than in the open in all seasons; the reverse was the case with Noctuidae, while "other families" showed no distinct preference to a certain locality. An analysis was, then, carried out to determine the "woodland" and the "open country" species in each group, and a number of the commoner species could be classified with a fair degree of reliability.

The sex preportions in the catches showed a definite preponderance of males, with a certain constancy in the seasonal variations of female percentages from one year to another in Geometridae and Noctuidae. When the effect of the main weather factors was tested separately on males and females of Noctuidae in the month of peak catch (July) in both years, both sexes were found to be affected in almost the same degree.

In the study of the relation between the percentage of females in the catch and the abundance of individuals it appeared that the increase in both males and females was more or less proportional.

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MORPHOLOGICAL ADAPTATIONS IN THE MAXILLAE OF THREE SPECIES OF MOSQUITO LARVAE

[*Diptera* : *Culicidae*]

(with 3 Text-Figures)

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INTRODUCTION

This paper is a part of an extended study of the morphological adaptations of the mouth parts of the mosquito larvae. Particular references are represented by three different species with variable feeding habits, namely *Culex* (*Barraudius*) *pusillus* Macq., *Culex molestus* Forsk. and *Anopheles pharoensis* Theob.

The adaptations of the mouth parts of the mosquito larvae have engaged the attention of several investigators. Many interesting examples of the maxillae in mosquito larvae have been described and figured in several papers dealing with the morphology of the mouth parts. Cook (1944a) gave a comprehensive analysis of the mouth parts of several widely different species. Farnsworth (1947) investigated the functional aspects and the musculature of the mouth parts of the fourth stage larva of *Anopheles quadrimaculatus* Say. The author studied the mouth parts of the larval instars of a wide variety of species (Shalaby, 1956 and 1957, a, b, and c). In the course of studies, the author noticed anatomical variations in the maxillae, the mandibles, the labia and the labral brushes which probably would account for the differences in the feeding habits of the larvae and their food requirements. Waddington (1952) explained how the structural modifications which happen to make the animal more adapted to its environment come into being.

The study reported in the present paper was undertaken with the primary objective of revealing the anatomical modifications taken place in the maxillae

of the fourth stage larvae of these three different species; and to discuss the relationship between these morphological modifications as adaptive characters and the feeding habits of the larvae. Because of their importance in the establishment of morphological modifications, the feeding habits of these three larvae were studied. The maxillae are located ventrad of the mandibles, forming together with the mandibles the side walls of the mouth opening. The epipharynx cephalad and the labium-hypopharynx complex caudad form the roof and the floor of the mouth opening respectively.

The specimens studied were collected by the author from locations in the suburbs of Alexandria. *Culex pusillus* and *Culex molestus* were reared for several generations, in the laboratory. *Anopheles pharoensis*, on the other hand, was collected from its breeding places as third and fourth instar larvae.

FEEDING HABITS OF THE LARVAE

While general information has been available on the feeding habits of mosquito larvae, scant literature exists on this subject. Workers on this subject have agreed that the mechanics of feeding are complicated. Wesenberg-Lund (1943) reported on the action of the mouth parts of the mosquito larvae that sweep particles from the water. He stated that there are tufts of hairs on the apices of the maxillae and well developed fringes which are borne on the ventral side of the mandibles that take part in the sweeping action of the larva, in addition to the action of the labral brushes. At the laboratories of the University of Illinois, analysis of the mechanics of feeding by using motion photomicrography has been accomplished by Horsfall (unpublished). According to Horsfall (1955), the larvae of mosquitoes ingest nutriment in the form of particulate matter ranging from that of bacterial size to that clearly visible; or might be in the form of other living organisms that are as large as themselves.

It is noticed that the larvae of *Anopheles pharoensis* feed on particulate matter that floats on the surface film. The film seems at times, to be drawn towards the larva as a sheet. The larvae of *C. pusillus* and *C. molestus*, on the other hand, ingest particulate matter that is suspended throughout the medium. At times, they feed at the surface by bending the body in the shape of a U and vibrate the brushes in the film as the head rotates in spirals around the pivotal siphon. The suspended particulate matter, however, is gathered by creating a current caused by the rapid motion of the labral brushes and all the parts of the mouth, across the mouth opening. There, the constant pharyngeal pumping and suction causes the food matter to flow into the mouth. In his study of the bionomics of *C. pusillus*, the author reported that the larvae are found mostly suspended 3-4 mm. below the surface where they feed by filtering the food particles by the rapid movement of the labral brushes and the other parts of the mouth (Shalaby, in press). It is important to note

that the larvae of *C. molestus* often cling to submerged surfaces where potential food substances might be adherent. The food substances would be dislodged by racking the hairs of the brushes attached to the different parts of the mouth,over the surface. This form of feeding has been referred to as "grazing", a form which is best illustrated in the larvae of *Aedes aegypti* Linn. Numerous structural modifications are obviously required to adapt life under these different food requirements and feeding habits.

HOMOLOGY OF THE MAXILLA WITH THAT OF GENERALIZED INSECTS

The descriptive terminology employed for the different parts of the maxilla is that of the author (Shalaby, 1956 and 1957, a, b, and c). Several attempts towards the homology of the mouth parts of the mosquito larvae with those of the generalized insects have been accomplished by various investigators. Different interpretations have, therefore, resulted and accordingly different terms for the same structure have been introduced. This has created a state of nomenclatorial non-uniformity. The work of Cook (1944a) is considered to be most conclusive.

In his study of the mouth parts of the larval instars of *Anopheles quadrimaculatus* (Say), *Aedes aegypti* Linn. and *Culex quinquefasciatus* (Say), the writer gave a more or less complete discussion of the literature on this subject. In his own interpretations concerning the homology of the mouth parts with those of generalized insects, the writer discussed the homology of the maxilla and the terminology of its different lobes.

DESCRIPTIONS

Maxilla of the fourth stage larva of *Culex* (*Barraudius*) *pusillus* Macq.

(Figure 1)

The maxilla is oval in shape. Its mesal margin is prominently convex, from which arise a great number of setae that overlap each other forming a sieve-like structure. The caudal region of the mesal margin is provided with numerous fine setae which extend more or less mesad. There are numerous long and fine hairs which arise along the entire mesal region of the maxilla. These hairs tangle and overlap each other. Another cluster of fine hairs arises from the meso-caudal region of the cardostipes (CDST). The chitinous ridge (CR) extends along the meson of the maxilla between the lacinia (LC) and the galea (GA) cephalad, and ends in the caudal region of the cardostipes, where it fuses caudad with the mesal point of articulation of the maxilla to the ventral wall of the head capsule. The ridge is highly

sclerotized, pigmented and slightly sinuate. There are two membranous appendages (MACR) articulating with the distal end of the proximal third of the chitinous ridge, whose function is not known. These two appendages are slightly pigmented, somewhat pointed and extend meso-cephalad.

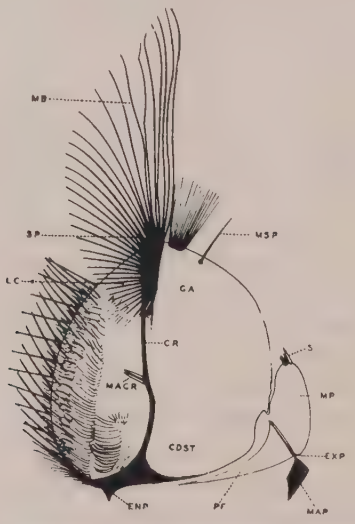

FIG. 1: Ventral aspect of the left maxilla of the fourth stage larva of *Culex* (*Barraudius*) *pusillus* Macq.

The maxilla is articulated to the head capsule by means of two points; a mesal entoparartis and a lateral exoparartis (ENP and EXP). The entoparatis is located at the meso-caudal end of the cardostipes, while the exoparartis is located at the caudo-lateral end of the maxillary palpus (MP). There is a highly pigmented and sclerotized quadrangular shaped maxillary apodeme (MAP) connected with the lateral end of the exoparartis This apodeme is invaginated from the ventral wall of the head to help in the articulation of the maxilla to the head capsule. The palpifer (PF) is located caudo-laterad of the cardostipes. It is sclerotized, pigmented and triangular shaped, the base of which bears the palpus. The palpus is one-segmented, with a slightly convex lateral margin. It is less sclerotized and less pigmented than the rest of the maxilla. The palpus bears on its distal end five minute papilliform structures which are referred to as the sensora (S). They are uneven in size.

A maxillary brush (MB) is located at the cephalic end of the maxilla. It consists of numerous hairs ranging from 35-50 in number. The hairs are long laterad and shorten gradually mesad giving the shape of a fan. At the cephalic end of the lacinia arises a short and pigmented spine (SP) which extends meso-cephalad. The lateral margin of the maxilla is convex. At the cephalic region of the galea arises a somewhat long maxillary spine (MSP) which is heavily pigmented and extends

latero-cephalad. Mesad of the maxillary spine, there is a fan shaped cluster of setae. The setae are simple, relatively short, somewhat rigid and extend cephalo-laterad.

Maxilla of the fourth stage larva
of *Culex molestus* Forsk.

(Fig. 2)

The maxilla is oval in shape. It is more pigmented than that of *C. pusillus*. The mesal margin is convex from which arise numerous rigid and stiff setae that overlap each other. The mesal region is provided with numerous short but stiff spines which are directed mesad. The meso-caudal region is provided with three closely-packed clusters of fine hairs. It is noticeable that the caudal region of the mesal margin is provided with eight to ten pectinate spines (PCSP), which are long distad and shorten gradually proximad. These spines are curved, rigid and pectinate along their mesal margin. The chitinous ridge (CR) is slightly sinuate, pigmented and sclerotized. It fuses with the entoparartis (ENP) caudad. The two membranous appendages of the chitinous ridge (MACR) are attached to the proximal end of the distal third. The entoparartis and the exoparartis (EXP) are similar in location to those of the *pusillus*. A similar invagination from the ventral wall of the head, forming the maxillary apodeme (MAP) is present caudad of the exoparartis.

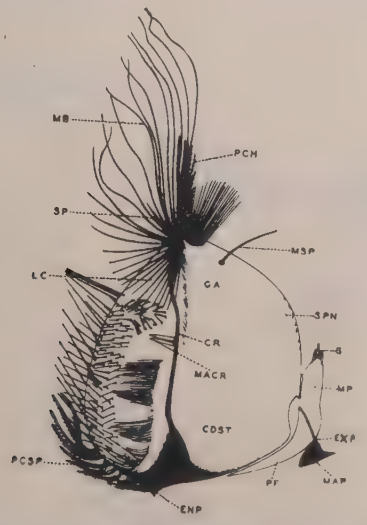

FIG. 2: Ventral aspect of the left maxilla of the fourth stage larva of *Culex molestus* Forsk.

The palpifer (PF) is more slender than that of the *C. pusillus*. The maxillary palpus (MP) is somewhat small and more slender than that of the *pusillus*. Its lateral

margin is slightly sinuate. Five sensoria (S) are located at its distal end. The maxillary brush (MB), though not as packed as in the *pusillus*, yet the hairs are less flexible. A cluster of short hairs similar to that in the *pusillus* is attached cephalad of the galea (GA). It is noted that there is a group of pectinate hairs (PCH) ranging from seven to ten in number, which are attached laterad of the maxillary brush. They are pectinate along their lateral margin. A short pigmented spine (SP) is connected to the cephalic end of the lacinia (LC). The lateral margin of the maxilla is prominently convex. At its cephalic region, a curved, pigmented and rigid maxillary spine (MSP) is present. It must be noticed that the lateral margin is provided with a number of spinules (SPN) which are sharply pointed.

Maxilla of the fourth stage larva
of *Anopheles pharoensis* Theob.

(Figure 3)

The maxilla is flat and trapezoidal in shape. It is composed of two parts, the cardostipes (CDST) and the palpus (MP). The cardostipes is rectangular in shape. It is clothed on both the ventral and the dorsal sides by numerous fine setae. The setae arising from the cephalic margin are of moderate length and curved mesad. There are stout, straight and shorter setae that tangle and overlap the curved ones. Arising from the mesal end of the cephalic margin are fairly long, stout setae

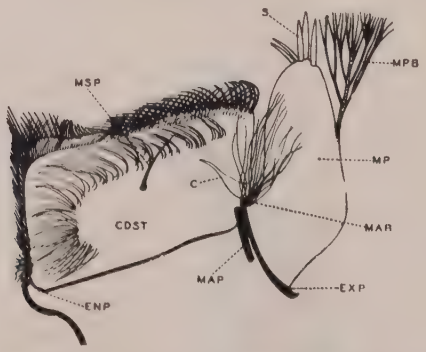

FIG. 3: Ventral aspect of the maxilla of the fourth stage larva of *Anopheles pharoensis* Theob.

that are slightly curved. Most of these setae tangle and overlap each other to form a sieve-like structure. Along the mesal margin of the cardostipes arise short but stout setae which extend meso-cephalad. There are also fine hairs arising from a more ventral plane which tangle and overlap the mesal setae. The various groups of fine hairs which cloth the ventral surface of the cardostipes vary much in length,

direction and density. Near the proximal end of the mesal margin is connected a sclerotized area which extends caudad to form a sclerotized and pigmented rod that extends laterad until it articulates with another sclerotized rod which extends upward. This forms the mesal point of articulation of the maxilla to the ventral wall of the head. The caudal margin of the cardostipes is sclerotized along its entire length. There is a spine which arises from the middle of the ventral aspect of the cardostipes which is here referred to as the maxillary spine (MSP). It is pigmented and of a moderate length. The proximal end of the lateral margin of the cardostipes is pigmented, slightly sclerotized and bears a narrow cleft (C).

The maxillary palpus is considerably large and long enough to extend cephalad beyond the cardostipes. It is dilated at the middle and tapers at its proximal region where it becomes more or less sclerotized on its outer and inner margins. The sclerotization extends caudad forming a short sclerotized rod which serves as the lateral point of articulation with the head capsule. Arising from the distal end of the palpus are five papilliform sensoria (S) which are larger than those of *C. pusillus* and *C. molestus*. From the proximal end of the distal third of the lateral margin of the palpus is developed a unique bristle (MPB) which arises on a more or less elevated area. The bristle has a relatively short stalk and extends distad beyond the sensoria. The stalk divides to several branches which divide again and again to a great number of very fine branches, producing the shape of a tree.

In the angle between the cardostipes and the palpus is located a heavily pigmented and sclerotized apodeme (MAP). It is of a moderate length and extends along the side of the caudo-mesal margin of the palpus. Arising from the distal end of the maxillary apodeme is a relatively short, stout and plumose bristle (MAB). It lies obliquely across the cardostipes and the palpus at their point of articulation. The side branches of this bristle are relatively long and flexible. It is believed that the maxillary apodeme acts as a support for the articulation of the maxilla with the ventral wall of the head. The maxilla articulates with the cranium at two points, a mesal entoparartis and a lateral exoparartis (ENP and EXP). The cardostipes, however, is articulated with the ventral wall of the head along its entire caudal length. The exoparartis is located at the proximal end of the maxillary palpus.

DISCUSSION

The maxilla of the mosquito larva in general, has departed radically from the generalized type of maxilla. Nevertheless, additional structural modifications have taken place as demonstrated in the maxillae of *Culex pusillus*, *Culex molestus* and *Anopheles pharoensis*. It was evident that the differences in the shape and the structure of the maxillae of these three species are due to the differences in the feeding habits of the larvae.

The most striking observation is the flat shaped cardostipes and the apparent

reduction of the galea and the lacinia in the maxilla of the larva of *A. pharoensis*. This is in contrast to the oval shaped body of the maxillae of the larvae of *C. pusillus* and *C. molestus*, which consist of the galea and the lacinia cephalad and the cardostipes caudad. Other prominent characteristics of the maxilla of *A. pharoensis* is the absence of a brush and the presence of a large-sized palpus which bears a tree-shaped bristle on the distal region of its lateral margin. The absence of the brush and the flat shaped cardostipes appear to be the result of the surface feeding habit of the larva which is apparently due to its position, being parallel to the water surface.

Probably the most obvious characteristics of the maxillae of *C. pusillus* and *C. molestus* is the presence of a brush and a considerable reduction in the size of the palpus in comparison with that of *A. pharoensis*. This seems to be well adapted to the filtering feeding method of the larvae. It is believed that the possession of rigid pectinate spines, stiff pectinate hairs and spinules in the maxilla of *molestus* rather than in *pusillus* is probably due to the occasional grazing feeding habit of the larvae of the former which would help in racking over submerged surfaces.

Striking features in the morphological adaptations of the maxillae of the different instars of one species appear in the work of the author on the mouth parts of the larval instars of *Psorophora ciliata* Fab. (SHALABY, 1957c). In the newly-hatched first instar larvae, the maxilla is more or less triangular in shape and possesses a brush. In the second, third and fourth instars, the maxilla becomes oval in shape and possesses three short, rigid and stiff haired combs instead of the brush. This demonstrates a striking adaptation to the filtering feeding habit practiced by the first instar larvae and to the predacious feeding habit practiced by the advanced instars of this species.

Though this paper is concerned only with the structural differences taken place in the maxillae, yet the variability in certain characters even with the scant specimens at hand, indicated a direct response to such behaviour as food preferance and feeding habits of the larvae, in the expression of morphological characters. WADDINGTON (1942) suggested that if an animal is subjected to unusual circumstances to which it can react in an adaptive manner, the development of an adaptive character might itself becomes so far canalised that it continued to appear even when conditions return to the previous norm. In 1952, WADDINGTON introduced a new theory called "genetic assimilation of acquired characters". He believes that the genetic assimilation might take place through the rise of new genes by mutation. He also explained that the genetic constitution of any animal becomes so ready to make the particular response to the environmental conditions, that finally the response occurs on its own without requiring the environment to touch it off. ROSS (1951) says that all the members of the family Culicidae come from a common origin. A knowledge of this, leads to the belief that such morphological modifications occurring in the maxillae of the larvae of these three different species, are probably anticipatory adaptations which have occurred earlier in the life history of the mosquito as its evolution proceeds.

SUMMARY

The morphology of the maxillae is described. The maxilla of *Anopheles pharoensis* is composed of a rectangular shaped cardostipes and a large palpus. The maxillary brush and the palpifer are absent. The maxillae of *Culex pusillus* and *C. molestus* are oval in shape. They are composed each, of a galea, a lacinia, a cardostipes and a relatively small palpus. The maxillary brush and the palpifer are present. The maxilla of the *molestus* differs from that of the *pusillus* in the possession of pectinate spines at the meso-caudal region, pectinate hairs at the cephalic region and spinules at the lateral region.

The feeding habits of the larvae are observed. *A. pharoensis* has the surface feeding habit. *C. pusillus* has the filtering feeding habit. *C. molestus* acquired the grazing feeding habit in addition to the filtering method of feeding.

An account is given on the relationship between the morphological modifications occurring in the maxillae and the variability in the larval feeding habits.

The development of these morphological adaptations from the evolutionary point of view is discussed.

ACKNOWLEDGMENTS

The author expresses his gratitude to Prof. M. M. Ramadan, for facilities offered.

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POPULATION STUDIES ON THE BLACK SCALE, *CHRYSOMPHALUS FICUS* ASHMEAD:

II. INTERACTIONS OF FACTORS AFFECTING DISTRIBUTION OF POPULATION

[*Hemiptera-Homoptera* : *Coccoidea*]

(with 1 Text-Figure and 2 Tables)

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INTRODUCTION

The writers in a previous paper (1957) dealing with the distribution of population have studied the effect of heights and directions in three different seasons in a sunny and shady tree of *Ficus nitida*. It was more convenient, then, to deal with each season and with each factor separately. As was previously noted, in order to follow the population dynamics it was necessary to study the interactions between these different factors. A multiple factor analysis of variance was carried out for all items of the population in both heights and directions. The symbols S, T, H and D are given for seasons, treatments (sunny or shady), heights and directions respectively, and thus the symbols for the interactions between them are ST, SH and TH in case of heights and ST, SD and TD in case of directions. The results of analysis are given in Tables I and II where + and ++ are given for F values significant at probability levels of 5 and 1% respectively. An asterisk is given for F values significant at P levels between 5 and 10%. The figures used in this analysis are all calculated figures, e.g., the figure used to represent the number of insects per 10 leaves at any height is the mean of a whorl of eight cardinal directions at that height. In the same way, the figure used to represented the number of insects per 10 leaves at any direction is the mean of a column of six heights at that direction.

A. HEIGHTS

1. The interaction between treatments and heights (TH)

If the factor of seasons was ignored and the mean number of insects per ten leavesat each height was calculated during the three seasons in both the sunny and shady trees, then the result obtained will show the interaction between treatments and heights. It is clear from Table I, that this interaction is consistently insignificant for the total population and all its constituent items. The means for the total population are as follows :

	Heights in metres					
	3	4	5	6	7	8
Sunny tree	1114	1756	1680	1985	2088	2693
Shady tree	1151	1227	2268	2334	2392	2699

The general trend for the distribution of insects is almost the same in both treatments. The numbers of insects, as is clear from the above means and from the curve (Fig. 1A), are almost equal especially at the lowest (3 metres height) and highest heights (8 metres height), with slight tendency of the shady tree to harbour more insects in the heights inbetween (5-7 metres height).

2. The interaction between seasons and treatments (ST)

In this case heights are ignored and a single mean is calculated to represent the number of insects per 10 leaves in each season, both in the sunny and shady trees. It is clear from Table I that this interaction is almost always significant. The means for the total population are as follows :

	Nov.–Dec.	March–April	July–August
Sunny tree	2210	2651	796
Shady tree	1705	2861	1470

Two conclusions can be drawn from these figures and from the curve shown in Fig. 1B. (1) The highest population is in the season of March - April, followed by November - December and the lowest is in the July - August count. (2) The population of insects in the sunny tree is only higher than that of the shandy tree in November - December, but less in both March - April and July - August. These two conclusions are in agreement with the climatogical factors prevailing at the periods when the counts were made (Habib and Khalifa, 1957). These two conclusions have proved to be true in the cases of the total number of nymphs, number of dead nymphs, total number of adults and number of dead males.

In cases of the other items, where this interaction was significant, the population of insects did not exactly follow the above rule, Thus in cases of number of dead adults, total number of females and number of dead females the population of

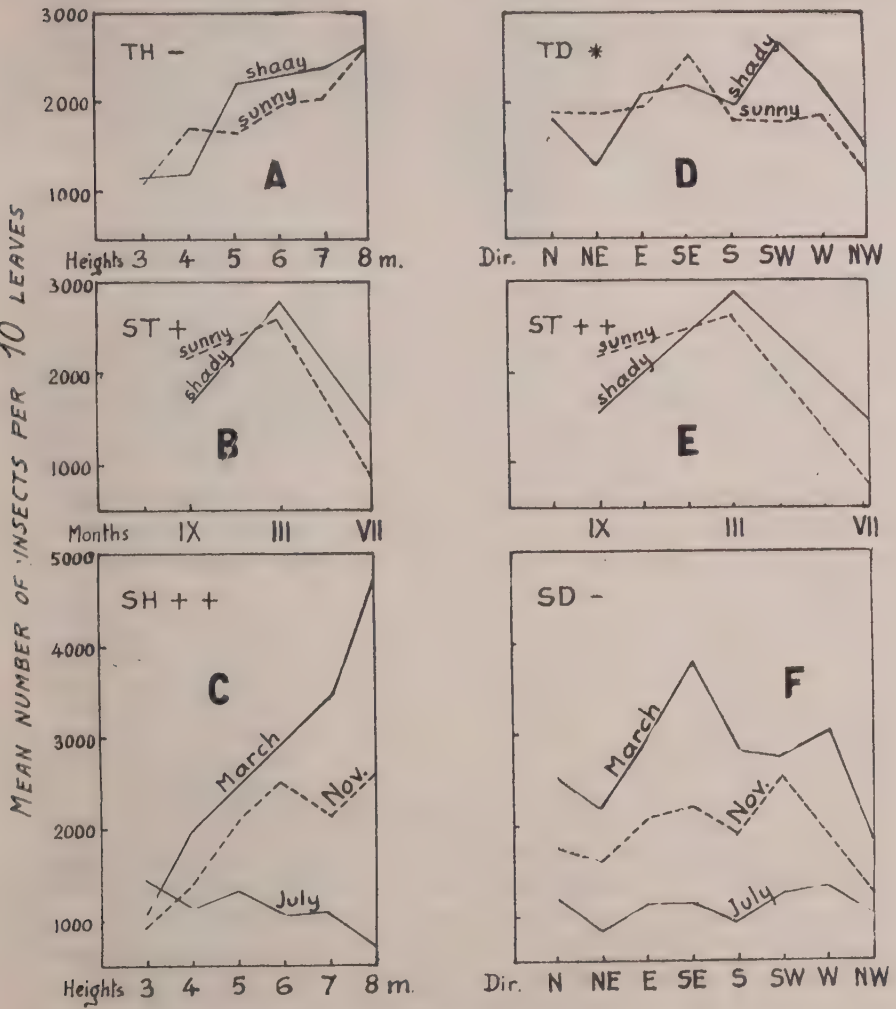

FIG. 1: Curves showing the interaction between factors for the total population.

insects in the July - August count is higher than that of November - December. This abnormal distribution is probably due to the accumulation of dead females from the previous counts. The means of the numbers of dead females given below show that there is a gradual increase of density through the successive counts.

	Nov.–Dec.	March–April	July–August
Sunny tree	158	303	205
Shady tree	108	287	461

The means of the total number of males on the other hand, show gradual decrease, the highest number being in the November/December count. This may be due to either extra emergence of males during the season or to the fact that the empty shells of the living males are easily blown off by wind and never have the chance of accumulation. The means were as follows :

	Nov.–Dec.	March–April	July–August
Sunny tree	410	251	131
Shady tree	340	383	175

This interaction, however, proved to be insignificant in cases of number of living nymphs, number of living females, number of living ovipositing females, number of living males, percentage of survivors of nymphs and percentage of survivors of females. The most striking phenomenon in these cases is that the difference between the populations in the sunny and shady trees are rather negligible in both seasons of March - April and July - August, it is only clear in the season of November - December. Thus the means of the number of living nymphs for instance are as follows :

	Nov.–Dec.	March–April	July–August
Sunny tree	384	622	60
Shady tree	247	657	72

3. The interaction between seasons and directions (SD)

In this case the factor of treatments is ignored, i.e., the mean of each height in each season is estimated irrespective of the treatment. This is comparatively the most significant interaction, the distribution of insects in the different heights is significantly different in the different seasons. The means of such distribution are given below for the total population and is shown in the curve, Fig. 1C.

	Height in metres					
	3	4	5	6	7	8
Nov.–Dec.	970	1389	2073	2550	2155	2610
March–April	1045	1934	2485	2862	3433	4773
July–August	1383	1152	1564	1063	1133	705

Two conclusions can be drawn: (1) the highest population is of March - April count followed by that of November - December and July - August counts respectively; (2) in both March - April and November - December counts the least number of insects is present in the lowest height (3 metres height) and increases gradually towards the higher heights. In July - August count, on the other hand, the distribution is nearly reversed, the lower parts of the tree harbour more insects and the number of insects decreases gradually upwards. This is also in agreement with the climatogical factors. The upper extremities of the trees are more favourable to the insects during the November - December and March - April counts and and much less soduring July - August. This sort of distribution holds true and significant for several other items of the populations. These items are : the total number of nymphs, the numbers of living and dead nymphs, the number of living ovipositing females and the percentage survivors of nymphs.

Although the item of the number of dead females was also significantly affected, yet it did not follow the above rules. It differed in the fact that the number of dead insects in the July - August count was almost consistently higher than in November - December or March - April counts. The means were as follows :

	Heights in Metres					
	3	4	5	6	7	8
Nov.–Dec.	96	80	131	188	155	149
March–April	217	304	331	284	293	343
July–August	334	312	426	388	419	119

This is undoubtedly due to the accumulation of dead females from the previous seasons. These unusual numbers, however, resulted in causing several items to be insignificantly affected, e.g., total number of adults, number of dead adults, total number of females and the percentage survivors of females.

The number of living females, although insignificantly different, yet it nearly follows the above mentioned two rules. The number of dead males is insignificntly different. It differed from the above rules in the fact that the distribution of males in July - August count showed nearly the same nature as in the other two counts, i.e., the numbers increased with the increase of heights. This resulted in causing the total number of males to be only significant at P level of 10%.

B. DIRECTIONS

1. The interaction between treatments and directions (TD)

The same way of calculation was adopted for directions. Thus, for this interaction the factor of seasons was ignored and the mean number of insects per

10 leaves was estimated for each direction for the three seasons both in the sunny and shady trees. Although mostly insignificant, yet the TD has shown to be slightly more significant than in the case of heights (TH). For the total population (Fig. 1D), the means for the different directions arranged in a clockwise fashion are as follows:

	Directions							
	N	NE	E	SE	S	SW	W	NW
Sunny tree	1907	1887	1998	2543	1849	1776	1892	1226
Shady tree	1867	1374	2103	2235	1978	2644	2298	1449

And although it is only significantly different to the level of P 10%, yet it can be noticed that in case of the sunny tree the highest population is in the SE direction while the lowest population is in the NW direction which is exactly opposite. The same phenomenon occurs in the shady tree but in different directions, thus the highest population is in he SW while the lowest is in the NE direction. On the whole the southern hemisphere of the trees harbours more insects.

The other significantly different items of the population are: the total number of adults, and its two constituting components, i.e., the total number of females and the total number of males; the number of living males and the percentage survivors of females are also significantly different. The distribution of insects in case of the total number of adults and its constituting components follows the same rule, i.e., the highest number of insects is in the SE and the lowest number is in the NW in case of the sunny tree and in the SW and NE directions respectively in the shady tree. For the total males, there is another peak for the number of insects in the shady tree in the E direction, and the means are as follows:

	Directions							
	N	NE	E	SE	S	SW	W	NW
Sunny tree	247	305	361	389	250	219	185	179
Shady tree	245	198	429	278	221	374	284	259

This occurs in both the constituting components of this item, i.e., the number of living males and number of dead males, inspite of the fact that the latter being insignificantly different. In case of the percentage survivors of females the means are as follows :

	Directions							
	N	NE	E	SE	S	SW	W	NW
Sunny tree	41	42	46	39	33	36	44	35
Shady tree	29	33	41	43	35	30	26	30

In the sunny tree the highest percentage is in the E direction and the lowest in the S; whereas in the shady tree they are in the SE and N directions respectively.

In spite of this interaction being insignificant in all other items constituting the population, yet there is a point in the case of nymphs which is worth noting. In case of living nymphs the number is nearly always higher in the sunny than in the shady tree; the means being:

	Directions							
	N	NE	E	SE	S	SW	W	NW
Sunny tree	365	346	377	569	364	340	347	171
Shady tree	339	241	346	455	362	355	342	172

For the dead nymphs the matter is reversed, the numbers being nearly always higher in the shady tree and the means are as follows:

	Directions							
	N	NE	E	SE	S	SW	W	NW
Sunny tree	847	787	824	1082	886	866	944	564
Shady tree	841	610	897	1145	1008	1234	1148	600

This caused the percentage survivors of nymphs to be consistently and uniformly higher in the sunny than in the shady tree. The means are as follows:

	Directions							
	N	NE	E	SE	S	SW	W	NW
Sunny tree	22	24	27	28	25	22	23	19
Shady tree	18	22	23	22	18	19	16	17

2. The interaction between seasons and treatments (ST)

A look at Table II, shows that this is the most significant interaction, being significantly different in all the items constituting the population. As in the case of heights, the directions are ignored, and the mean number of insects in all directions is estimated for each season and for both treatments. It gives a picture which is exactly similar to that of heights and follows the previously mentioned two rules, i.e., (1) the highest population is in the March - April count, followed by that of November - December and the lowest is in July - August; (2) the population in the sunny tree is only higher than that of the shady tree in November - December, but

less in both March - April and July - August. Thus for the total population (Fig. 1E) the means are as follows :

	Nov.–Dec.	March–April	July–August
Sunny tree	2218	2646	790
Shady tree	1618	2890	1473

The same applies to the total number of nymphs, number of deas and alive nymphs, total number of adults and the number of ovipositing females. In case of the number of dead adults the number of insects in July - August is exceptionally higher especially in the shady tree. This is clearly due to the accumulation of dead females as previously stated. The total number of females deviates from the above rules in the fact that the sunny tree harbours more insects in March - April count. The number of living females is higher in the shady tree than in the sunny tree throughout the three counts, but inspite of that the percentage survivors of females is consistently higher in the sunny tree. The total number of males and the number of living males deviate in the fact that the number of insects is highest during the November - December count. The percentage survivors of nymphs, inspite of being insignificantly different, yet it is also consistently higher in the sunny tree during the three seasons.

3. The interaction between seasons and directions (SD)

This interaction as appears from Table II is mostly insignificant. When we ignore the factor of treatments, then the difference between the different seasons at each direction seems to be insignificant. However, there are two facts which are also noticeable : (1) the highest population in all directions is in the March - April count, followed by that of November - December and the least is in July - August.; (2) the highest population is in the southern parts of the trees. Thus for the total population (Fig. 1F) the means are as follows :

	Directions							
	N	NE	E	SE	S	SW	W	NW
Nov.–Dec.	1748	1578	2071	2217	1891	2564	1924	1355
March–April ...	2690	2269	2942	3785	2855	2781	3008	1817
July–August	1224	1045	1140	1165	996	1287	1354	842

This is the case with all the items of the population where the difference between the different seasons in the different directions appears to be insignificant. In cases of the total number of nymphs, the number of living nymphs and the number of ovipositing females, the difference is significant. Thus in the items of nymphs the

TABLE I

The result of analysis of data for heights: —, result is insignificant; + result is significant at P level of 5%; ++, resut is significant at P level of 1%. The difference in those marked with an asterisk is significant at P level of 5–10%.

Item	TH	ST	SH
Total population	—	+	++
Total number of nymphs	—	*	++
Number of dead nymphs	—	+	++
Number of living nymphs	—	—	++
Total number of adults	—	+	—
Number of dead adults	—	++	—
Total number of females	—	+	—
Number of living females	—	—	—
Number of living ovipositing females	—	—	++
Number of dead females	—	++	++
Total number of males	—	*	*
Number of living males	—	—	++
Number of dead males	—	+	—
Percentage survivors of nymphs	—	—	+
Percentage survivors of females	—	—	—

TABLE II

The result of analysis of data for directions: —, result is insignificant; +, result is significant at P level of 5%; ++, result is significant at P level of 1%. The difference in those marked with an asterisk is significant at P level of 5–10%.

Item	TD	ST	S D
Total population	*	++	—
Total number of nymphs	—	++	++
Number of dead nymphs	—	++	—
Number of living nymphs	—	++	++
Total number of adults	+	++	—
Number of dead adults	—	++	—
Total number of females	*	++	—
Number of living females	—	+	—
Number of living ovipositing females	—	++	++
Number of dead females	—	++	—
Total number of males	+	++	—
Number of living males	—	++	—
Number of dead males	+	+	—
Percentage survivors of nymphs	—	—	—
Percentage survivors of females	+	++	—

line of March - April count is not consistently the highest as in the other cases, but intersects with that of the November - December count at certain directions. In case of number of ovipositing females the number of insects in March - April count is exceptionally much higher than in the other two counts. This may be due to the coincidence of making the count in the period of oviposition in that season.

SUMMARY

The writers in their first paper, dealing with the distribution of pupulation of the black scale in a wild infestation have treated each season separately. It appeared, then, that the factors of height (H) and direction (D) were significant, sometimes in the sunny tree, and sometimes in the shady tree or in both. In this paper the interactions between the different factors are studied.

On ignoring the factor of seasons and taking the means as representing the number of insects in the whole year, then the interactions between the other factors such as TD (treatment × directions) and TH (treatment × heights) appear to be almost insignificant.

The factor of seasons has proved to be very important and its presence in any interaction causes it to be significantly different as in cases of ST (seasons × treatment), SH (seasons × heights) and SD (seasons × directions).

In case of the interaction TH (treatment × heights) the number of insects seems to be equal in both extremities of the trees in either treatment, i.e., the lowest height (3 metres height) and the highest height (8 metres height) with slight inclination of the shady tree to harbour more insects in the heights in between (5-6 metres height).

For the interaction TD (treatment × directions) the highest population in the sunny tree is in the SE direction and the lowest is in the opposite direction of NW. In the shady tree the same occurs, but in different directions. Thus the lowest is in the NE direction while the highest population is in the SW direction.

For the interaction of ST (seasons × treatment) in both cases of heights and directions the highest population appears to be in the March - April count, followed by that of November - December, while the lowest is in July - August. The number of insects in the sunny tree is more than that in the shady tree in November count, but less in the other two counts.

In case of the interaction of SH (seasons × heights) the highest population again appears to be in March - April count, followed by November - December and July - August. In March - April and November - December counts the least number of insects is present in the lowest height (3 metes height and the number increases gradually upwards, but in July - August count the matter is nearly reversed.

For the SD (seasons × directions) interaction the population of insects is again highest in March - April count followed by the other two counts in the same

order. The southern parts of the trees proved to harbour more insects than the northern parts.

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ON THE POST-EMBRYONIC DEVELOPMENT OF A COMPOUND NERVE-GANGLION IN *LOCUSTA MIGRATORIA MIGRATORIOIDES* (R.-F.)

[*Orthoptera : Acrididae*]

(with 5 Text-Figures)

by A. M. AFIFI, M.SC.,

Zoological Institute, Munich.

I. INTRODUCTION

The metathoracic ganglion of *Locusta* represents a compound nerve centre which supplies parts of the body other than its own segment. The ganglion of the adult insect innervates certain organs characteristic of *Locusta* which lie far from each other (e.g. the BRÜNNER'S organ on the hind-femur and the tympanal organ on the first abdominal tergum).

The mode of innervation given by this ganglion in *Locusta* suggests that it may receive and respond to stimuli on the abdominal region as well. Therefore, it was found interesting to follow the development of this ganglion during the post-embryonic life of the insect.

The necessary locusts were supplied from the Zoological Institute in Hamburg and were reared at 30° C. and 70% R.H. The egg pods developed in humid sand at 35° C. and 80% R.H. In order to obtain the extremely short living pro-larval stage, which does not exceed a few seconds, it was found necessary to accomplish hatching artificially under a dissecting binocular. The nymphal instars were defined mainly by investigating the terminalian structures (DIRSH, 1950).

By microscopical preparation complete dehydration and use of xylol were avoided, for they caused shrinkage and brittleness of the fine nerves. The detached ganglia were mounted directly after staining in an alcohol-soluble medium, namely euparal. Sagittal and tangential sections were made through detached ganglia

(7μ. thick) and through the whole thorax of smaller forms (12μ. thick). In the former case BLUM-SJÖBRING solution (10% formol) was used as a fixative and SEKI's haematoxylin as a stain. In the latter case, fixation was carried out by mercuric chloride (after HELLY) and staining by MAYER's haematoxylin + eosin.

The author wishes to express his sincere thanks to Prof. M. HAFEZ (Cairo) and Prof. W. JACOBS (Munich) for their valuable advice during the work, to Dr. V. JAKOVLEV (Hamburg) for supplying the necessary material, and to Mr. A. ALFIERI, Secretary General of the Entomological Society of Egypt.

II. THE POST-EMBRYONIC DEVELOPMENT

In the newly hatched pro-larva the metathoracic segment is supplied with four pairs of separate nerve ganglia, the anteriormost of which (Fig. 1, M) belongs to the metathorax. The remaining three pairs (I-III), however, correspond to embryonic abdominal ganglia which shift from their own segments forwards in a late embryonic stage (ROONWAL, 1937). The four pairs of ganglia are connected lengthwise with one another by thick connective (K) on either side. In addition to these connectives, 4 distinct transverse commissures (C) join the corresponding ganglia with each other crosswise. Both connectives and commissures are more distinguishable from the ventral side (Fig. 1).

Histological investigation reveals that each ganglion consists mainly of two separate groups of nerve cells, the ganglion cells (Fig. 2, GC). The nerve fibres of each group extend inwards and aggregate in a distinct thick mass, the glomerulus (GL). The connectives extend between the successive glomeruli as a pair of thick long bands of nerve fibres (K). The commissures (C), however, are represented by four short bands of nerve fibres extending crosswise between the corresponding glomeruli. It seems that both connectives and commissures are extensions of the glomeruli-fibres. The latters being in turn aggregations of the ganglion cell-fibres, it could be accepted that the commissures and connectives provide an indirect means of co-ordination between the different groups of ganglion cells.

After the pro-larval stage, the following changes take place (Fig. 3, I-IV), leading to the gradual fusion of the 4 pairs of ganglia in a compound nerve centre:

1. — The metathoracic commissure shortens immediately after the pro-larval moult. In the early 1st nymphal instar the metathoracic ganglion represents a median bilobed structure.

2. — During the 1st instar the three abdominal commissures shorten rapidly. As a result of this shortening, the double connectives approach each other and finally attach together except for three small holes representing the rudiments of the interganglionic spaces (Fig. 2, S).

3. — In the second stage the metathoracic ganglion loses its bilobed character. The double connectives fuse completely in a thick median band (B) on either side

of which adhere three abdominal ganglia. The latters are still quite free from each other and from the metathoracic ganglion.

4. — During the 3rd instar the successive ganglia approach one another through the shortening of the median band connecting them. At the end of this stage the abdominal ganglia represent three protrusions (Fig. 4, I-III) on either side.

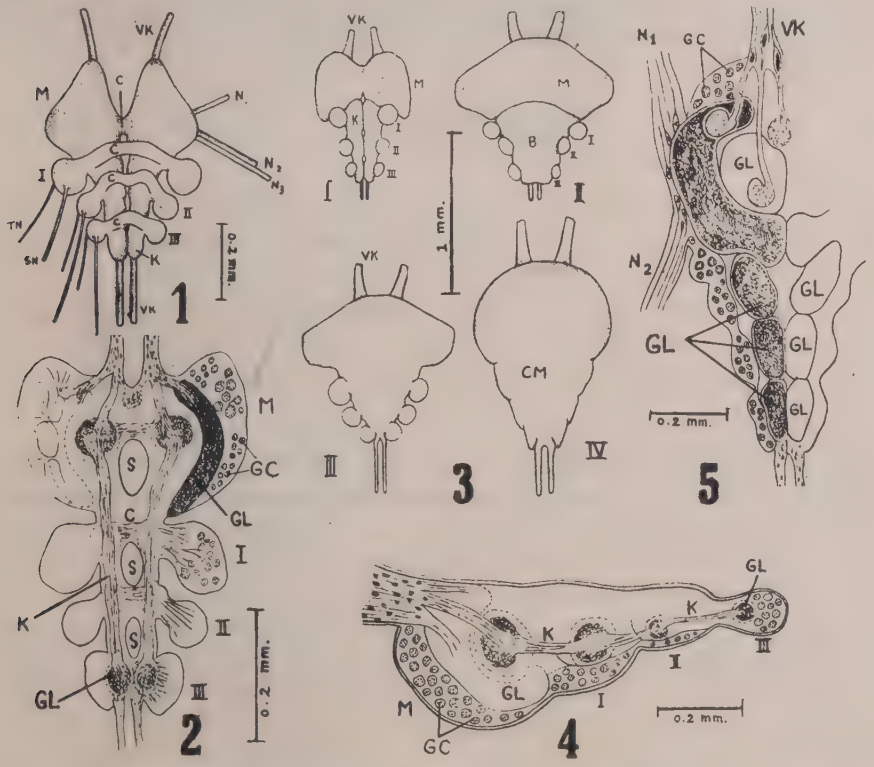

FIG. 1: Pro-larva, metathoracic ganglia (ventral view). — FIG. 2: First stage, tangental section. — FIG. 3 (I–IV): Developmental changes after the pro-larval stage. — FIG. 4: Third stage, sagittal section. — FIG. 5: Fourth stage, tangential section.

(I–III, embryonic abdominal ganglia; B, median band; C, transverse commissure; CM, compound metathoracic ganglion; GC, ganglion cells; GL, glomeruli; K, longitudinal connective; M, metathoracic ganglion; N_1, tegumentary-muscular nerve; N_2, jumping leg-nerve; S, inter-ganglionic spaces; VK, ventral nerve chain connective.

5. — After the 3rd nymphal moult these protrusions fuse with the metathoracic ganglion. In the fourth stage the four pairs of glomeruli (Fig. 5, GL) lie very close to one another and no trace of connectives or commissures could be observed between them.

III. CONCLUSION

The post-embryonic development of the metathoracic ganglion of *Locusta migratoria migratorioides* (R. - F.) was followed by anatomical and histological investigations. The individuality of the first three pairs of embryonic abdominal ganglia could be traced until the third nymphal instar is reached. Complete fusion of these ganglia with the metathoracic ganglion in a compound nerve centre is attained during the fourth instar and not before hatching as ROONWALL (1937) states.

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DAS BISHER UNBESCHRIEBENE MÄNNCHEN VON *ATOMOSCELIS TOMENTOSUS* REUTER

[*Hemiptera-Heteroptera* : *Miridae*]

(mit 10 Abbildungen)

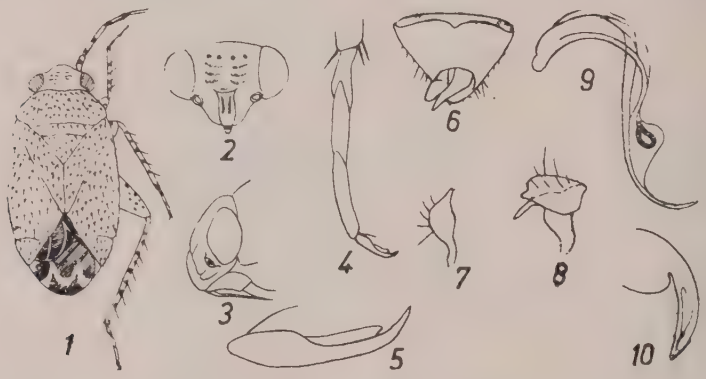
von EDUARD WAGNER, Hamburg.

Von obiger Art beschrieb REUTER 1904 nur das Weibchen. Mir ist nicht bekannt, dass eine Beschreibung des Männchen späterhin erfolgt sei. Jetzt sandte mir Herr Prof. H. PRIESNER, Kairo, liebenswürdigerweise eine Anzahl Tiere der Art, unter denen sich auch ein Männchen befindet. Ich halte es für angebracht, hier eine Beschreibung desselben zu geben:

Gestalt oval, etwa doppelt so lang wie breit (Fig. 1). Blassgrün. Pronotum, Scutellum und Halbdecken mit schwarzen, steifen, rückwärtsgerichteten Haaren bedeckt, die aus kleinen schwarzbraunen Flecken entspringen, die vor allem im hinteren Teile der Halbdecken deutlich sind. Kopf und Unterseite mit weissen, glänzenden Haaren bedeckt, die sich auch stellenweise zwischen den schwarzen Haaren der Oberseite finden.

Kopf (Fig. 2) stark geneigt, breiter als hoch, Augen gross, braun. Scheitel etwas mehr als doppelt so breit wie das Auge, mit je einem weissen Fleck am Auge und in der Mitte des Vorderrandes, der sich auf der Stirn fortsetzt. Stirn jederseits mit 3 bräunlichen Querstreifen und 4 dunklen Flecken am Hinterrande. Stirnschwiele deutlich von der Stirn abgesetzt (Fig. 3), im basalen Teil mit 2 dunklen Längsstreifen, stark gekrümmt und im distalen Teil rückwärts gerichtet. Kehle schief. Die weisslichen Fühler entspringen unmittelbar neben der unteren Augenecke (Fig. 2); 1. Glied dick und kurz, etwa so lang wie das Auge breit ist, in der apikalen Hälfte mit grossem schwarzem Fleck; 2. Glied nahe dem Grunde und in der Mitte mit je 2 schwarzen Flecken, die einen Ring bilden, der auf der Ober- und Unterseite offen ist; 3. Glied bräunlich, am Grunde schmal schwarz, 0,6 × so lang wie das 2. und kaum länger als das 4.

Pronotum sehr kurz und breit, 1,4 × so breit wie der Kopf samt Augen, im vorderen Teile weiss gefleckt. Schwielen undeutlich. Schildgrund frei. Basalwinkel des Scutellum und ein Mittelstreif weisslich. Halbdecken etwa die Hinterleibsspitze erreichend, Cuneus sehr kurz und breit. Membran schwarzgrau, Adern weisslich; hinter der kleinen Zelle ein weisser Fleck und von der Spitze der grossen Zelle führt ein gegabelter weisser Fleck nach hinten, der mit demjenigen der anderen Halbdecke die Form eines M bildet (Fig. 1). Spitze beider Zellen schwärzlich.



Atomoscelis tomentosus Reut. (Männchen):

FIG. 1: Gestalt, 16×. — FIG. 2: Kopf von vorn, 31.5×. — FIG. 3: Kopf seitlich, 31.5×. — FIG. 4: Hinterfuss, 31.5×. — FIG. 5: Klaue von aussen, 33.6×. — FIG. 6: Genitalsegment von oben 31.5×. — FIG. 7: Linker Paramer von oben, 84×. — FIG. 8: Rechter Paramer von oben, 84×. — FIG. 9: Vesica des Penis seitlich, 84×. — FIG. 10: Spitzenteil der Theca seitlich, 84×.

Unterseite grün, hell behaart. Schnabel weisslich, die Spitze der Mittelhüften etwas überragend, das 1. Glied dick, den Hinterrand des Kopfes deutlich überragend. das 4. Glied schwärzlich. Beine weisslich, mit heller Behaarung. Schenkel im Spitzenteil dicht mit schwarzen Flecken bedeckt. Auch die Vorderhüften mit einigen dunklen Punkten. Schienen mit hellen Dornen, die aus grossen schwarzen Punkten entspringen und etwas länger sind als die Schiene dick ist. Spitze der Schienen dunkel. Tarsen hell, distal etwas angedunkelt. An den Hintertarsen (Fig. 4) ist das 3. Glied lang, aber etwas kürzer als das 1. und 2. zusammen. Klauen lang und schlank (Fig. 5), nur distal etwas stärker gekrümmt; Haftläppchen lang und schmal, die Klauenmitte überragend, mit den Klauen verwachsen.

Genitalsegment des Männchens (Fig. 6) kurz und breit, kegelförmig. Rechter Paramer (Fig. 7) sehr klein, flach, in der Mitte am breitesten, aussen mit langen Haaren. Linker Paramer (Fig. 8) kurz und dick. Hypophysis abwärtz gekrümmt, Sinneshöcker dick, mit kurzer, dicker Spitze, behaart. Vesica des Penis (Fig. 9) kräftig, S-förmig gekrümmt, distal in eine lange, gekrümmte Chitinspitze auslaufend.

Sekundäre Gonopore weit vor der Spitze in einer breiten, membranösen Fläche liegend. Spitzenteil der Theca (Fig. 10) schlank, stark gekrümmt.

Länge = 1,95mm., grösste Breite = 0,94mm., Breite des Pronotum = 0,82, des Kopfes 0,58, des Scheitels = 0,30, des Auges = 0,14mm., Länge der Fühlerglieder : 1 = 0,13, 2 = 0,37, 3 = 0,225, 4 = 0,215mm.

Das mir vorliegende Männchen (Allotypoid) wurde von Herrn Prof. PRIESNER im April 1957 in Ägypten (Sakkara Road) an *Heliotropium luteum* gefunden. Da gleichzeitig auch zahlreiche Weibchen und Larven auf der Pflanze festgestellt wurden, ist anzunehmen, dass sie die Wirtspflanze der Art ist.

Ich möchte nicht versäumen, Herrn Prof. PRIESNER auch hier für seine liebenswürdige Unterstützung meiner Arbeiten zu danken.

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MARMOTTANIA PRIESNERI NOV. SPEC.

[*Hemiptera-Heteroptera* : *Lygaeidae*]

(mit 4 Abbildungen)

von EDUARD WAGNER, Hamburg.

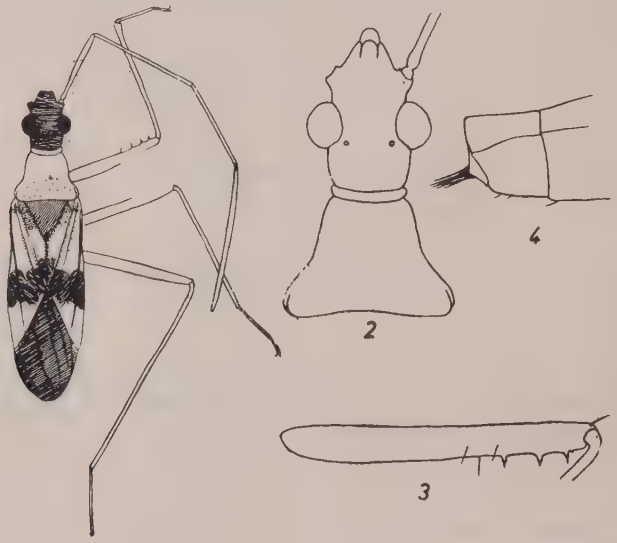
Langgestreckt (Fig. 1), fast 5 × so lang wie das Pronotum breit ist, mit sehr langen Fühlern und Beinen. Schwach glänzend, die Halbdecken fast matt. Fast kahl. Gelb bis gelbbraun, die Halbdecken zum Teil gelbweiss.

Kopf lang und schmal (Fig. 2), ohne Punktgruben, braun. Scheitel 1,6 × so breit wie das vorstehende, schwarze, grob gekörnte Auge. Hinter den Augen ist der Kopf halsartig verlängert, aber mit gerundeten Schläfen, die halsartige Verlängerung etwa so lang wie das Auge. Stirnschwiele die Wangen deutlich überragend. Fühlerhöcker nach vorn divergierend und weit kürzer als das Auge (etwa 0,67 × so lang). Fühler strohgelb, mit äusserst feiner Behaarung, die Gesamtlänge der Fühler übertrifft die Körperlänge um etwa die Hälfte. Länge der Glieder: 1 = 1.6, 2 = 2.2, 3 = 1.85, 4 = 3 mm. Das 2. und 3. Glied etwas schlanker als das 1. und 4., das letzte leicht gekrümmt. Das Rostrum überragt die Hinterhüften beträchtlich, sein 1. Glied erreicht etwa die Mitte zwischen dem Hinterrand der Augen und demjenigen des Kopfes, das 2. Glied erreicht die Vorderhüften.

Pronotum (Fig. 2) gelbbraun, mit sehr deutlichem Halsring, der durch eine tiefe Furche abgetrennt ist, die jedoch keine Punktgruben aufweist. Vorderer Teil des Pronotum schmal, ohne Punktgruben, gewölbt. Hinter der Mitte erweitert sich das Pronotum stark, zwischen vorderem und hinteren Teil eine deutliche Querfurche. Hinterer Teil mit Punktgruben. Hinterwinkel abgerundet, mit einer gekrümmten Längsfalte. Hinterrand leicht eingebuchtet. Scutellum dunkelbraun, mit einzelnen Punktgruben. Seiten des Pronotum deutlich geschweift, der Rand fein gekielt.

Halbdecken (Fig. 1) gelbweiss, Clavus an Grund und Spitze breit braun. Corium im Grundwinkel mit braunem Fleck und hinter der Mitte mit brauner Querbinde, Spitze des Corium hell. Clavus am Innenrande mit einer deutlichen Reihe von Punktgruben, im übrigen Teil mit zwei und regelmässigen Punktreihen. Corium am Schildrande und an der Kubitalader mit je einer regelmässigen Punkt-

reihe; im hinteren Teile, von der braunen Querbinde ab, zerstreute Punktgruben, die aussen dichter stehen. Radialader des Corium im basalen Teile unmittelbar neben dem Rande verlaufend und sich etwa in Höhe der Scutellumspitze von ihm trennend. Dort erweitert sich das Corium leicht nach aussen. Membran einfarbig rauchbraun, das Ende des Hinterleibes erreichend.



Marmottania priesneri nov. spec.:

FIG. 1: Männchen (7,2×). — FIG. 2: Kopf und Pronotum von oben (18×). — FIG. 3: Vorder schenkel (18×). — FIG. 4: Ende des Abdomens des Männchens seitlich (18×).

Unterseite von Kopf und Brust braun, vom Hinterleib gelb. Beine hellgelb, Schenkel mit einzelnen langen Haaren. Vorderschenkel (Fig. 3) leicht verdickt, auf der Unterseite nahe der Spitze 3 bedornte Tuberkeln. Schienen sehr lang und dünn, mit feinen, hellen Dornen, Vorderschienen an der Spitze leicht verbreitert. Füsse lang und schlank, 1. Glied der Hintertarsen fast 3 × so lang wie das 2. und 3. zusammen. Genitalsegment des Männchens (Fig. 4) schwarz, Mitte seiner Hinterfläche (Unterseite) buckelartig gewölbt, auf dem Buckel ein Büschel langer Haare.

Länge: Männchen = 6.3-7.0 mm, Breite des Pronotum = 1.3-1.4 mm.

M. priesneri n. sp. ist die 3. Art der Gattung und unterscheidet sich von den beiden bisher beschriebenen Arten durch die abgerundeten Hinterecken des Pronotum und die einfarbig rauchbraune Membran. *M. simonis* Put. ist weit kleiner, das Männchen 5mm. lang. Kopf, Pronotum und Scutellum sind einfarbig schwarz, mit Ausnahme des Halsringes des Pronotum, der Teil des Corium hinter der braunen Querbinde ist braun eingefasst, die Membran hat an der Spitze einen weissen Fleck, das 2. Fühlerglied ist das längste, das Rostrum reicht nur bis zu den Hinterhüften,

in der Querfurche hinter dem Halsring des Pronotum befindet sich eine Punktreihe, die Hinterecken des Pronotum sind in eine nach hinten gerichtete Spitze ausgezogen, die Halbdecken lassen die beiden letzten Hinterleibssegmente unbedeckt, das Genitalsegment des Männchens trägt auf dem Höcker in der Mitte seiner Hinterfläche einen langen griffelartigen Fortsatz, der waagerecht nach hinten ragt, von der Mitte ab verdickt und nach oben gekrümmt ist.

M. rungsi Vid. ist gleichfalls nur etwa 5mm. lang (Weibchen), Kopf, Pronotum und Scutellum sind braun, der halsartige Teil des Kopfes hinter den Augen ist hinten plötzlich verengt und die Schläfen dadurch eckig, das 1. Fühlerglied ist kürzer als der Kopf, und der Fühlerhöcker ragt nicht nach aussen, ist aber so lang wie das Auge. Das Rostrum erreicht nur die Mittelhüften. Die Hinterecken des Pronotum sind wie bei *M. simonis* in eine nach hinten gerichtete Spitze verlängert, der Clavus ist einfarbig hell und die Hinterecke des Corium breit braun, die Membran hat an der Spitze einen weissen Fleck, die Unterseite ist hell, die Vorderschenkel haben 4 deutliche Zähne und 4-5 Borsten. Das Männchen ist unbekannt.

MATERIAL: 3 Männchen aus Aegypten (Südl. Sinaigebiet): Wadi El-Legaa, 12.viii.43, Männchen, leg. H.S. EFFLATOUN + M. SHAFIK; Karm Alam, Wadi Isla, 12.iv.40, Männchen, leg. M. TEWFIK.

Die Art lebt in der montanen Steppe des Süd-Sinai wahrscheinlich am Boden unter nicht ganz flach liegenden Steinen, kommt nachts hervor und fliegt dann auch ans Licht.

Belegstücke im Museum der Universität Kairo und in meiner Sammlung. Ich widme diese Art Herrn Prof. Dr. H. PRIESNER, Kairo, dessen hervorragende Verdienste um die Erforschung der Hemipterenfauna Aegyptens bekannt sind. Ihm verdanke ich auch das vorliegende Material.

SCHRIFTEN-NACHWEIS

PUTON, A. (1887) : *Rev. d'Ent.*, Caën, VI: pp. 302-303.

VIDAL, J. (1931) : *Bull. Soc. Sci. Nat. Maroc*, XXXI : p. 60.

UNE ESPÈCE PALÉARCTIQUE DU GENRE *DIPLOPLECTRON* FOX

[*Hymenoptera* : *Sphecidae*]

(avec 5 Figures)

par W. J. PULAWSKI

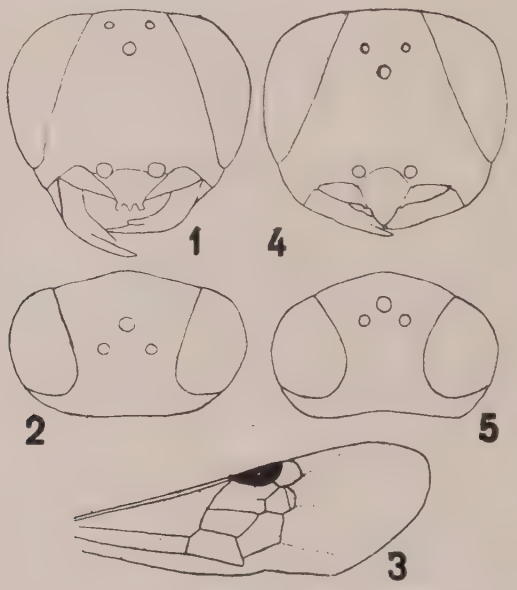
Le genre *Diploplectron* Fox comprend dix espèces connues, dont l'une est sud-africaine et les autres habitent l'Amérique du Nord. Dans les collections de M. A. Alfieri (Le Caire), auquel vont mes plus sincères remerciements, j'ai constaté la présence d'un couple de ces insectes, récoltés en Egypte. Il m'a aussi été possible de capturer encore une femelle dans ce Pays. L'espèce est nouvelle pour la science.

Diploplectron palaearcticum n. sp.

Holotype : Wadi Mitla (Sinaï), 21. iv. 1938, femelle (coll. A. Alfieri); Allotype : Wadi Digla, près du Caire, Juin, mâle (coll. A. Alfieri); Paratype : Guizeh, près des pyramides, 15. xii. 1957, femelle (coll. mea).

Femelle. — Joues presque aussi longues que le diamètre du funicule. Lobe médian du clypéus tridenté au bord antérieur, non séparé des lobes latéraux par des dents (Fig. 1). Fossette antennaire normale, article 3 des antennes 3.75 fois plus long que large à l'extrémité et 1.25 fois plus long que le 4e, ce dernier 2.4 fois plus long que large à l'extrémité; dernier article 2.4 fois plus long que large à la base. Front nu, lisse et brillant, avec quelques points disséminés, peu profonds et peu visibles. Espace entre l'ocelle antérieur et l'un des postérieurs plus petit que l'espace post-ocellaire, celui-ci presque égal à l'espace oculo-ocellaire (SOL: POL: OOL = 6: 9: 8). Au niveau des ocelles postérieurs, tout près des yeux, on voit de chaque côté une impression longitudinale, très peu concave, mais bien distincte par sa surface chagrinée. Tête derrière les yeux bien développée (Fig. 2). Les poils du dessous de la tête sont foncés, fins, aussi longs que l'article 4 des antennes. Pronotum, mésonotum, scutellum et postscutellum lisses et brillants, imponctués; au bord antérieur du mésonotum il y a, sur les côtés, quelques soies foncées très fines. Méso-

pleures lisses et brillantes, avec seulement quelques points peu visibles. Mésosternum avec des points dispersés, et de fines soies foncées, courbées vers l'arrière, dont les plus longues (situées vers les côtés du mésosternum) sont plus courtes que celles du dessous de la tête. Aire dorsale du propodeum nue, nettement chagrinée, et, sauf tout devant, lisse aux bords. Faces latérales du propodeum avec de fines stries obliques, peu nettes; face postérieure lisse au milieu, légèrement sculptée sur les côtés qui sont pourvus de fins poils blanchâtres. Hanches antérieures lisses, avec de très petits points dispersés, chagrinées vers la ligne médiane. Fémurs antérieurs en dessous avec une rangée de soies foncées dont les plus longues dépassent les 3/4 du diamètre



Diploplectron palaearcticum n. sp.:

FIG. 1: Tête de la femelle, vue de face. — FIG. 2: La même, vue d'en haut. — FIG. 3: Aile antérieure de la femelle. — FIG. 4: Tête du mâle, vue de face. — FIG. 5: La même, vue d'en haut.

maximum d'un fémur. Tibias pourvus de poils très courts. Peigne des tarses antérieurs assez long, l'épine située à l'extrémité du métatarse est aussi longue que les deux suivants articles réunis, celle qui se trouve à l'extrémité de l'article 2 plus longue. Du côté externe du métatarse il y a 4 épines, du 2e article 2 épines, les 3e et 4e articles avec une seule épine chaque. L'arête interne du métatarse avec 5 fines épines, un peu plus longues vers l'apex, et avec une frange de cils aboutissant à la dernière épine. Avant-dernier article presque 1.5 fois aussi long que large. Aux fémurs médians il n'y a que 2 ou 3 très courts poils à la face inférieure, tout près de la base. Aux fémurs postérieurs on voit en dessous une rangée de 6 ou 7 soies

foncées dont celles qui se trouvent vers la base sont d'un quart plus longues que le diamètre maximum d'un fémur, et celles qui se trouvent vers l'apex mesurant seulement le quart de ce diamètre. Aux ailes antérieures (Fig. 3) la cellule radiale est très courte, deux fois plus large que longue au bord antérieur. Troisième cellule cubitale très étroite. Abdomen brillant, très faiblement chagriné. Aux sternites, les bords postérieurs déprimés sont délimités par des soies foncées, dispérsées, assez raides. Sixième tergite sans soies, aire pygidiale absente.

Corps noir, à l'exception des parties suivantes. La lamelle du clypéus et les mandibules (sauf vers la base et vers l'apex) ferrugineux jaune. Fémurs (sauf les genoux) noirs, tibias antérieurs ferrugineux jaune, jaunes vers la base; tibias intermédiaires et postérieurs brun noir, ferrugineux (holotype) ou jaune (paratype) vers la base et l'apex; tarses ferrugineux, ceux de devant un peu plus clairs que les autres. Tubercules huméraux noirs, tegulae, plaques alaires et nervures jaune pâle. Sixième tergite ferrugineux dans le tiers apical. Longueur 4.5 mm.

MÂLE. — Mandibules simples, sans dilatations ni angles au bord inférieur, avec de fines touffes de poils dans la moitié de la longueur. Joues aussi longues que les 2/3 de la plus petite distance inter-oculaire, plus longues que la largeur des mandibules à la base. Le lobe médian du clypéus (Fig. 4) à surface brillante, dépasse nettement les lobes latéraux (qui sont chagrinés) et forme avec eux des angles bien marqués. Fossette antennaire normale, antennes simples, sans tubercules ou pointes aiguës aux extrémités des articles. Article 3 des antennes 3.2 fois plus long que large à l'extrémité et 1.5 fois plus long que le 4e, celui-ci 2.2 fois plus long que large à l'extrémité. Dernier article des antennes 2.75 fois plus long que large à la base. Face interne du scape avec des soies noires. Front presque nu, avec quelques très courts poils peu visibles et quelques points peu profonds, bombé, lisse et brillant, seulement vers la moitié de son hauteur, près des orbites internes des yeux, on voit des espaces chagrinés. La moitié supérieure du front est divisée par un sillon médian qui aboutit à l'ocelle antérieur. Espace entre l'ocelle antérieur et l'un des postérieurs un peu plus petit que l'espace post-ocellaire, celui-ci presque égal à l'espace oculo-ocellaire (SOL: POL: OOL = 6: 9: 8). L'espace entre les ocelles postérieurs et une ligne imaginaire indiquant la plus petite distance inter-oculaire au vertex est 2 fois plus grand que l'espace entre ces ocelles. A l'arrière des ocelles on voit deux impressions longitudinales, chagrinées et très légèrement concaves. Tête derrière les yeux bien développée (Fig. 5). Les poils du dessous de la tête sont blancs, non denses, en moyenne aussi longs que l'article 4 des antennes. Pronotum légèrement chagriné, mésonotum (sauf le bord antérieur), scutellum et post-scutellum brillants. Au bord antérieur du mésonotum il y a, en outre, quelques points peu nets, et de fins poils blancs, dont quelques-uns sont un peut plus longs, plus raides et plus foncés. Mésopleures lisses et brillantes, mésosternum brillant, avec des points épars et des poils blancs, plus longs que ceux du brod antérieur du mésonotum, mais plus courts que ceux du dessous de la tête. Aire dorsale du propodeum nue, nettement chagrinée, et lisse aux bords (sauf tout devant). Faces latérales et postérieure chagrinées, avec

des points peu profonds et des poils blancs dont les plus longs (qui se trouvent entre la face latérale et postérieure) égalent ceux du dessous de la tête. Hanches antérieures lisses, chagrinées vers la ligne médiane du corps. Fémurs antérieurs en dessous avec des poils blancs, un peu plus longs que la moitié de son diamètre maximum. Quatre premiers articles du tarse antérieur avec, aux extrémités, des épines aussi longuse que l'avant-dernier article, qui est une fois et demie aussi long que large. Fémurs intermédiaires et postérieurs avec quelques fines soies foncées en dessous, les plus longues (situées près de la base) dépassant un peu la moitié du diamètre maximum d'un fémur. Nervulation des ailes comme chez la femelle. Abdomen brillant, très faiblement chagriné.

Corps noir à l'exception des parties suivantes. Mandibules (sauf le tiers basal) et l'extrémité du clypéus ferrugineux. Fémurs (sauf les genoux) noirs, tibias antérieurs jaunes, intermédiaires et postérieurs brun ferrugineux, jaunes vers la base et l'apex; tarses brun ferrugineux. Tubercules huméraux noirs, tegulae, plaques alaires et nervures jaune pâle, celles qui délimitent les cellules radiale, 2e et 3e cubitales et 2e discoidale décolorées. Tergites 1, 2, la base du 3e et le 7e d'un ferrugineux très foncé. — Longueur 4.5 mm.

Le genre *Diploplectron* Fox se distingue du genre *Astata* Latr. par le fait que chez les mâles les yeux ne se touchent pas au vertex. Les femelles sont moins faciles à caractériser. On cite comme caractère distinctif l'étroitesse de la 3e cellule cubitale, mais chez *Astata flavoundata* Arnold, de l'Afrique du Sud, cette cellule est non moins étroite. D'après mes observations les femelles de *Diploplectron* Fox diffèrent de celles d'*Astata* Latr. par les joues bien développées. Le même caractère est souligné par ARNOLD (1923) dans la description de *Diploplectron kriegeri* Brauns. Faute des renseignements nécessaires sur des espèces nord-américaines, cette supposition ne peut pourtant pas être admise avec certitude.

THE ARTHROPOD FAUNA OF THE EGYPTIAN FARMYARD MANURE

(with 12 Text-Figures and 6 Tables)

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I. INTRODUCTION

Farmyard manure is used as an important fertilizer throughout the Egyptian cultivated land. Methods for preparing and storing this manure may differ more or less from one district to another; hence the difference in its physical, chemical and biological properties. The physical and chemical aspects are well investigated and various text-books on agricultural fertilizers give any information required in this respect. The faunal analyses, however, have been greatly neglected inspite of their importance both to the soil biologist and to the agronomist. The effect of applying the organic manure to the cultivated land was studied by IMMS (1923), MORRIS (1927) who found it to increase the magnitude of the soil fauna. In Egypt, BISHARA and EL-KIFL (1954) did not notice its effect on the magnitude of the earthworms due to the marked scarcity of these animals. HAFEZ (1939) investigated the fauna in the dung of various animals.

The present attempt aims to throw light on the arthropod fauna of some kinds of organic animal manures prepared and stored by ordinary farm methods. Winter and summer faunal contents of these manures will be discussed.

II. PROCEDURE

This trial was began on 1.11.1956 and ended on 10.2.1957 to investigate the manure fauna during winter. Sampling was also carried out during a summer period from 10.6.1957 to 20.8.1957. The procedure was as follows.

1. — The size of the sample was 1000 cc., obtained by a cube of 10 cm. in dimension.

2. — The fauna was extracted by the TULLGREN funnel method. The sample was kept in the funnel for at least 24 hours.

3. — The farmyard manure used was obtained from various sources to examine the effect of the kind of manure on the fauna existing. Four kinds of manure were examined in winter and three in summer. Twenty samples were obtained from every manure used in both periods. They were taken from the surface layer, no more than 30 cm. deep. The kinds of farmyard manures treated were as follows:

(*a*) The sheep manure tested in both periods was the dung of sheep mixed with the urine and wheat straw. It was dumped near the animals in heaps, each no more than one cubic meter and 40 cm. higher than the soil surface. The manure was exposed to sun in winter and summer.

(*b*) The cow manure was composed mainly of earth mixed with the dung and urine together with some plant organic materials as wheat straw. The manure was dumped near the animals in heaps of about three cubic metres. This manure was characterized by being always wet due to continuous addition of earth mixed with animal urine and dung.

(*c*) A large heap of organic manure (more than 20 cubic meters) was examined in winter. The heap was collected from organic manures of various sources, i.e. under cows, buffaloes, birds, etc., thus designated here as "mixed" manure. In summer similar heaps of mixed manure were examined. They were exposed to sun.

(*d*) The horse manure was gathered freshly from underneath the animals. It was entirely horse dung and urine mixed with a large quantity of wheat straw.

4. — In summer, the cow manure was in shade during the midday.

5. — Sheep, cow and mixed manures were used in winter and summer while the horse manure was used only in winter. As one TULLGREN apparatus was available, samples were taken alternatively from every kind of manure in both periods, that is to say, the samples of every kind of manure were not tested successively.

6. — The room temperature and the manure temperatures at a depth of about 20 cm. were recorded at the time of sampling. In the case of the horse manure, no temperature was taken because the manure was thinly distributed under the animals in a shaded place. The temperature of this manure was, therefore, considered the same as that of the room temperature.

7. — Some samples of the mixed manure were kept from 20.8.57 to 2.9.57 to allow the coleopterous larvae it contained to breed before it was extracted.

8. — The present work was carried out in the farm of the Faculty of Agriculture, Cairo University at Giza, Egypt.

III. EXPERIMENTAL RESULTS

A. Room and manure temperatures

The mean room temperature at twelve o'clock noon during winter was 17.2°C. while it was 31.4, 29.2 and 32.7°C. in the sheep, cow and mixed manures, respectively. During summer, the mean room temperature at twelve o'clock noon was 31.3°C. while it was 45.2 and 35.6 °C. in the sheep and cow manures, respectively. The comparative lower temperature of the cow manure was due to its high water content and to its less exposure to the sun. The temperature of the mixed manure in summer was not similar in all parts of the heap because it was not uniformly mixed. The lower and the higher extreme degrees were 38.9 and 49.4°C., respectively.

B. Arthropod fauna of the organic manure

1. Total Arthropod fauna

Figure 1 shows the means per cubic metre of the Arthropod fauna in the different organic manures, examined during winter and summer. Winter means were generally higher than summer means, especially in the case of the sheep and mixed manures. In the case of the cow manure, the summer mean was comparatively

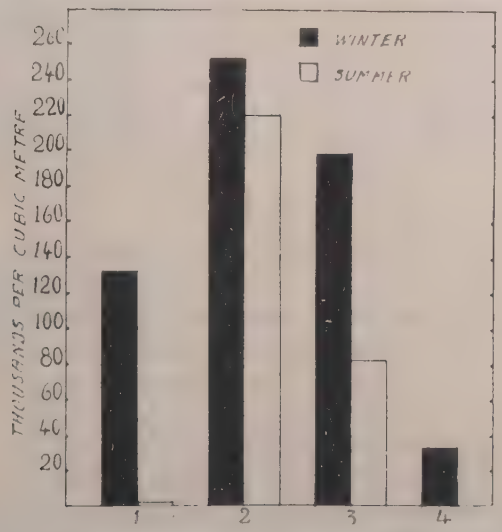

FIG 1: Means per cubic metre for total Arthropods in different organic animal manures examined (1, 2, 3 and 4: sheep, cow, mixed and horse manures, respectively).

less fluctuated due to more suitable temperature supervening. The comparative lower mean of the horse manure among other winter means might be due to its being treated freshly. Owing to the higher humidity and suitable temperature, the cow manure means were higher than other winter or summer means.

Although hundreds of thousands of the Arthropod organisms could be met with in various kinds of organic manures, yet these faunal magnitudes fluctuated greneatly, not only from one kind of manure to another, or from one season to another, but also from one sample to another in the same kind of manure. In winter, the ranges per cubic metre were from 14.000 to 365.000 specimens in the sheep manure, from 156.000 to 323.000 specimens in the cow manure, from 71.000 to 310.000 specimens in the mixed manure and from 18.000 to 63.000 specimens in the horse manure. In summer, the ranges per cubic metre were from nil to 11.000 specimens in the sheep manure, from 24.000 to 488.000 specimens in the cow manure, and from nil to 519.000 specimens in the mixed manure. The widest range was that of the mixed manure in summer while the narrowest was that of the sheep manure during the same season.

2. Crustacea

Specimens of this class were met with only in the mixed manure during winter at a rate of 2.200 individuals per cubic metre, ranging from nil to 8.000 specimens. They composed 1.10% of hte total Arthropod fauna in this manure. All specimens were sowbugs or Isopoda.

3. Myriapoda

Specimens of this class were also met with in the mixed manure only during winter at a rate of 600 individuals per cubic metre. They ranged from nil to 3.000 specimens and made up a small fraction (0.30%) of the total Arthropod fauna in this manure. Members obtained were only Diplopoda (Millipedes) of the group Pselaphognatha (tufted mellipedes). They were in different stages of development.

4. Insecta

Total Number: Figure 2 shows the means per cubic metre of the total insects existing in various manures during winter and summer periods. Although the sheep and mixed manure insect means were conspicuously higher in winter than in summer, the reverse took place in the case of the cow manure which was partially shaded and comparatively wetter during summer. The fluctuation of winter and summer means was more or less great; while the mean per cubic metre of the sheep manure winter mean reached 79.000 insects, it dropped to only 1.200 in summer, denoting the effect of the high temperature in that manure in this season. Though the winter mean of the cow manure was nearly similar to that of the sheep, it rose to 113.050 insects in summer due to comparative higher water content. The narrowest insect range met with was also in the case of the sheep manure in summer (from nil to

3.000 insects) while the widest range met with was in the cow manure in summer (from 10.000 to 394.000 insects).

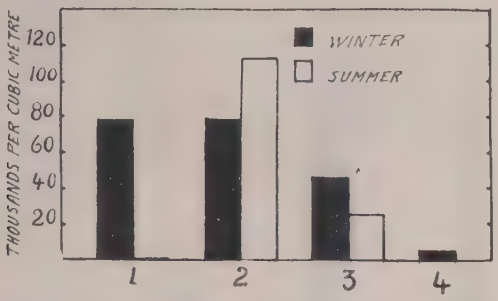

Fig 2: Means per cubic metre for total insects. (1, 2, 3 and 4: sheep, cow, mixed and horse manures, respectively).

Figure 3 shows the percentages of insects in total Arthropods in different manures. Insects composed more than 53% of the total Arthropod fauna in the sheep manure in winter and summer (58.76 to 53.33%, respectively). They made

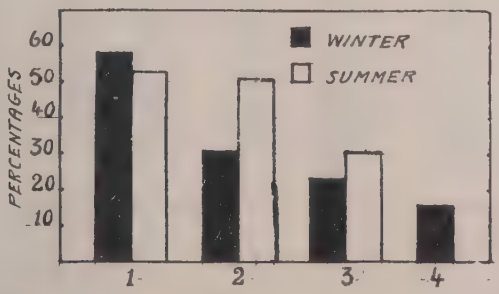

Fig 3: Percentages of insects in total Arthropods (1, 2, 3, and 4: sheep, cow, mixed and horse manures, respectively).

up 31.36 and 51.14% of that fauna in the cow manure in winter and summer, respectively. These percentages were 23.80 and 31.34, respectively, in the case of the mixed manure. The lowest percentage was that of the horse manure (16.40%) in winter.

The insect orders met with in the different manures examined were limited and their status will be discussed hereafter.

Diptera : Figure 4 illustrates the dipterous means per cubic metre. With the exception of the summer cow manure mean which was the highest (97.150 specimens), the winter means were conspicuously greater than summer means

especially in the case of the sheep manure. In this manure dipterous fauna ranged from 4.000 to 362.000 specimens per cubic metre in winter but from nil to 3.000 specimens only in summer. In the cow manure these ranges were from 15.000 to 128.000 specimens and from 400 to 384.000 specimens in the two periods, respectively.

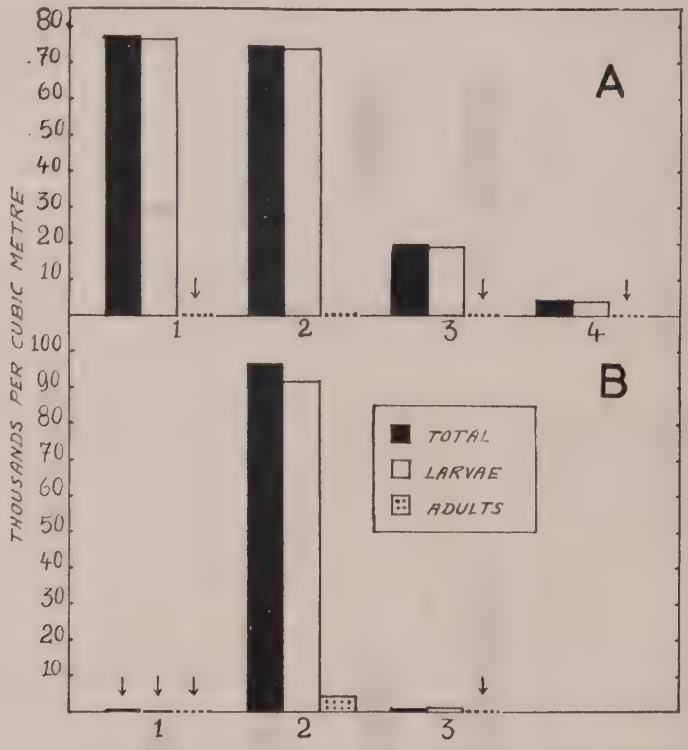

FIG 4: Means per cubic metre for dipterous fauna (A, winter means; B, summer means; 1, 2, 3 and 4: sheep, cow mixed and horse manures, respectively. Vertical arrows point to means less than 1000 specimens).

In the mixed manure the ranges were from 1.000 to 46.000 specimens and from nil to 11.000 specimens in these periods, respectively. The winter range in the horse manure was from 1.000 to 12.000 specimens per cubic metre.

Dipterous fauna composed a clearly large fraction of the insect fauna in the various kinds of manures examined. Its percentages were 98.16, 94.58, 42.06 and 84.21 of the total insects in winter in the sheep, cow, mixed and horse manures, respectively. These percentages were 79.17, 58.94 and 6.62 in the sheep, cow and mixed manures, respectively, in summer. It is noticed that the winter percentage exceeded the summer one of every manure. This large fraction of the dipterous fauna was due to the large number of the cyclorrhaphous larvae rather than the adults

as shown in Figure 5, with the exception of the sheep manure in summer. These larvae composed 97.41 and 93.32 % of the insect fauna in the sheep and cow manures respectively in winter (99.23 and 98.67 % in total Diptera). In the horse manure this percentage was 78.95 (93.57 in total Diptera) in winter. In the mixed manure, though the dipterous larvae percentage in winter was 40.80 (97 in total Diptera) it dropped to 5.29 (80 in total Diptera) in summer. Though the winter larvae percentages either in total insects or in total Diptera were higher than their summer percentages (Fig. 5), the adult winter percentages were, on the reverse, lower than the summer percentages in general. This may be due to the more rapid emergency of flies during summer. In the mixed manure, in summer, most of the muscoid flies extracted were with their ptillinum still expanded.

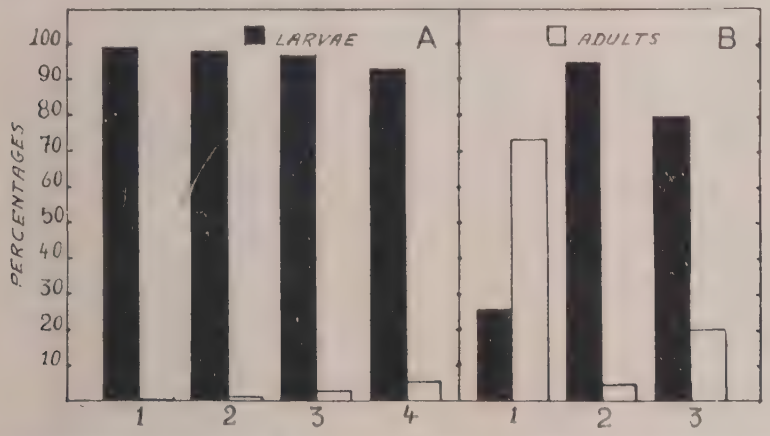

FIG 5: Percentages of dipterous fauna in total Diptera (A, winter percentages; B, summer percentages; 1, 2, 3 and 4: sheep, cow, mixed and horse manures, respectively).

Concerning the total dipterous fauna in total Arthropods, the winter percentage of every manure exceeded that of the summer percentage except in the cow manure. This also took place in the dipterous larvae. Winter percentage of flies of every manure was lower than the summer percentage in all cases.

Table I shows the status of flies in the different manures. As previously stated, the winter mean of flies in every manure was lower than the summer mean except in the mixed manure where the reverse took place. Neverthless, the number of flies extracted by the TULLGREN funnel does not show the true status of the fly fauna of the sample (EL-KIFL, 1957 and 1958) as some of these flies are possibly attracted by the light on the funnel and, consequently, are finally extracted with other fauna. This may interpret the higher percentage of flies than the larval percentage in the sheep manure in summer (Fig. 5). The mixed manure possessed the highest relative percentages of muscoid flies both in winter (75 %) and in summer (85.71 %). As

stated before, the large number of flies extracted in summer was possibly due to the comparative short life-cycle and consequently to the abundance of emerging flies. The flies belonging to the family Muscidae were of the smaller forms, smaller than the house fly, *Musca domestica*.

TABLE I

Adult Diptera: Means per cubic metres and percentages in total adults in various animal manures examined.

	Families	Winter				Summer		
		Sheep	Cow	Mixed	Horse	Sheep	Cow	Mixed
Means per cubic metre	Mycetophilidae	50	200	150	300	100	1050	50
	Chironomidae	100	300	—	—	300	1500	—
	Culicidae	50	100	—	—	200	600	—
	Sepsidae	100	150	—	—	—	100	—
	Muscidae	300	250	450	—	100	1250	300
	Total adults	600	1000	600	300	700	4500	350
Percentages	Mycetophilidae	8.33	20.00	25.00	100.00	14.29	23.33	14.29
	Chironomidae	16.67	30.00	—	—	42.86	33.33	—
	Culicidae	8.33	10.00	—	—	28.56	13.33	—
	Sepsidae	16.67	15.00	—	—	—	2.22	—
	Muscidae	50.00	25.00	75.00	—	14.29	27.78	85.71
	Total adults	100	100	100	100	100	100	100

COLEOPTERA : Figure 6 shows the means per cubic metre of coleoperous fauna. Total coleopterous winter means exceeded those of the summer for every manure with the exception of the cow manure. This phenomenon applied also with beetle means but the reverse took place with the larval means. The summer means of the latter exceeded those of winter with the exception of the sheep manure. Beetles seemed to be attracted by the suitable heat of manure in winter but were repelled by its high temperature in summer.

The winter number per cubic metre for coleopterous larvae ranged from nil to 6.000 specimens, from nil to 8.000 specimens, from nil to 21.000 specimens and from nil to 2.000 specimens in the sheep, cow, mixed and horse manures, respectively. In summer, the ranges were from nil to 1.000 specimens, from nil to 41.000 specimens and from nil to 10.000 specimens in the sheep, cow and mixed manures, respectively. Concerning beetles, the winter numbers ranged from nil to 2.000 specimens in the sheep, cow and horse manures, and from nil to 38.000 specimens in the mixed manure. In summer, beetles ranged from nil to 21.000 specimens, and from nil to 3.000 specimens in the cow and mixed manures, respectively, but no beetles were extracted from the sheep manure at that time.

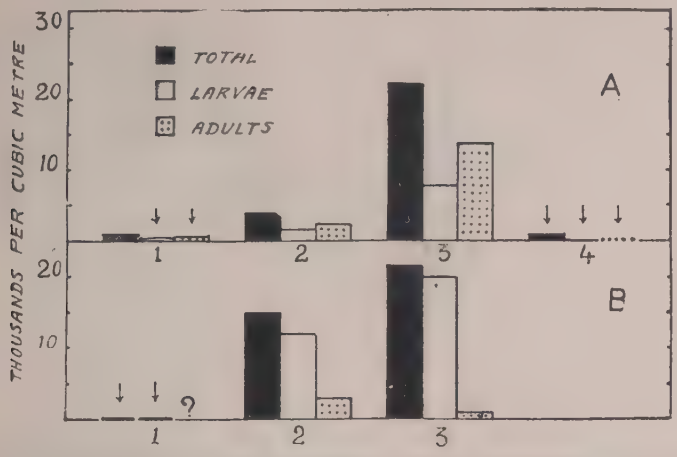

FIG. 6: Means per cubic metre for coleopterous fauna (A, winter means; B, summer means; 1, 2, 3 and 4: sheep, cow mixed and horse manures, respectively. — Vertical arrows point to means less than 1000 specimens).

Figure 7 shows the percentages of coleopterous fauna in total Coleoptera. During summer coleopterous larvae composed from 79.61 to 100% of the total coleopterous fauna, but in winter they formed only from 33.33 to 45% of this fauna. Beetles, on the reverse, formed a low percentage of coleopterous fauna in summer (from nil to 20.39%) but they made up from 55 to 66.67% of this fauna in winter.

Concerning the status of coleopterous fauna in the total insects the mixed manure ranked first either in winter or summer, composing 47.42 and 81.66% of the total insect fauna during the two periods, respectively. As most of coleopterous

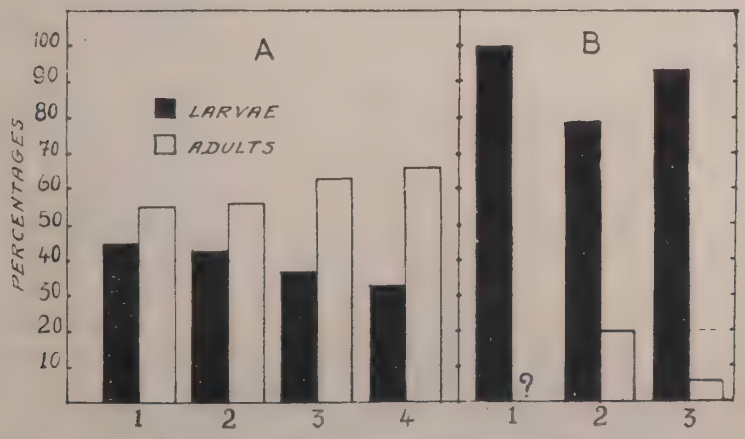

FIG. 7: Percentages of coleopterous fauna in total Coleoptera (A, winter percentages; B, summer percentages; 1, 2, 3 and 4: sheep, cow, mixed and horse manures, respectively).

fauna met with is predacaous, the high percentage of this fauna in this manure during summer could interpret the very low percentage of the dipterous fauna (especially larvae) of this manure at that time. The mixed manure also ranked first as it possessed the highest winter and summer percentages of coleopterous fauna in total Arthropoda (11.29 in winter and 25.59 % in summer). In the sheep and cow manures, coleopterous fauna composed only a small fraction of the insect fauna (about 1 to 5 % in the two manures respectively in winter, and about 13 to 21 % in summer).

Coleoptera ranked first as to number of families and genera extracted. As shown in Table II, eleven families and fourteen genera including at least sixteen species were met with. The table shows the means per cubic metre for every species met with. Table III shows the percentages of these species in total beetles in every manure. Among the winter species extracted, *Holoparamecus caularum* Aubé ranked first as it possessed a mean of 9.150 specimens per cubic metre (64.44 % of the total beetle fauna in the mixed manure). It was surprising to notice that *Tribolium confusum* Duv. ranked second, possessing 2.250 specimens per cubic metre in the mixed manure also in winter. It is well known that this species is a flour pest of worldwide is tribution. Besides dwelling in the organic manure, it was also met with in cultivated soil at Giza (El-Kifl, 1957). This shows that this species must have a wider distribution than already known hitherto. It could survive on organic material other than flour. *Aphodius lividus* Oliv. ranked first as to summer beetle means, possessing 500 specimens per cubic metre in the cow manure. It could be noticed also that some species were met with only in winter and others only in summer. Staphylinidae ranked first as to the number of species extracted.

The absence of beetles in the sheep manure during summer was conspicuous, due to the high temperature and activities of these insects.

Diptera and Coleoptera decidedly composed the principal insect fauna in the organic manure, as previously illustrated. Other insect orders were also met with, but with comparatively very minor magnitude. These orders include the following.

Psocoptera : The fauna of this insect group was found in sheep and mixed manures in winter at a rate of 450 and 5.000 specimens per cubic metre respectively, and in the cow manure in summer at a rate of 350 specimens. The widest range was from nil to 16.000 specimens per cubic metre in the mixed manure in winter.

Psocopterous fauna was represented only by *Liposcelis diverticulus*, belonging to Liposcelidae. This species alone composed 10.52 % of the total insect fauna or 2.50 % of the total Arthropod fauna in the mixed manure in winter.

Hemiptera : Hemipterous fauna was found only in the cow and mixed manures during summer at a rate of 100 and 2.900 specimens per cubic metre, respectively. It ranged from nil to 9.000 specimens in the mixed manure in summer. Hemipterous fauna was represented only by *Oxycarinus hyalinipennis* Costa, of the family Lygaeidae. Individuals of this species met with were all in the nymphal stage, composing 10.96 % of the total insects or 3.44 % of the total Arthropods in

TABLE II

Beetles fauna: Means per cubic metre in various animal manures examined.

Fauna	Winter				Summer		
	Sheep	Cow	Mixed	Horse	Sheep	Cow	Mixed
Lathridiidae:							
Holoparamecus caularum Aubé	—	1000	9150	—	—	—	—
Histeridae:							
Saprinus metallescens Er.	—	450	600	—	—	—	—
Ptilidae:							
Actidium aegypti Peyer.	—	350	1350	—	—	1550	—
Tenebrionidae:							
Tribolium confusum Duv.	—	—	2250	—	—	—	—
Thorictidae:							
Thorictodes heydeni Reitter.	100	—	100	—	—	—	—
Staphylinidae:							
Philonthus sp.	100	—	300	—	—	200	—
Platystethus cornutus Grav.	200	250	200	300	—	—	—
Trogophleous sp.	150	300	250	300	—	350	200
Oxytelus latiusculus boehmi Bernh.	—	—	—	—	—	300	—
Scarabaeidae:							
Aphodius lividus Oliv.	—	—	—	—	—	500	—
Cucujidae:							
Monotoma picipes Herbst.	—	—	—	—	—	—	300
Monotoma bicolor Villa.	—	—	—	—	—	—	200
Elateridae:							
Drasterius bimaculatus variegatus Buys.	—	—	—	—	—	200	—
Dermestidae:							
Anthrenus verbasci L.	—	—	—	—	—	—	250
Anthrenus minor Woll.	—	—	—	—	—	—	200
Anthicidae:							
Anthicus crinitus Laf.	—	—	—	—	—	—	200
Total	550	2350	14200	600	—	3100	1350

TABLE III

Percentages of beetles in various animal manures examined.

Fauna	Winter				Summer		
	Sheep	Cow	Mixed	Horse	Sheep	Cow	Mixed
Lathridiidae:							
Holoparamecus caularum Aubé	—	42.55	64.44	—	—	—	—
Histeridae:							
Saprinus metallescens Er.	—	19.15	4.23	—	—	—	—
Ptiliidae:							
Actidium aegypti Peyer.	—	14.89	9.51	—	—	50.00	
Tenebrionidae:							
Tribolium confusum Duv.	—	—	15.85	—	—	—	—
Thorictidae:							
Thorictodes heydeni Reitter	18.18	—	0.70	—	—	—	—
Staphylinidae:							
Philonthus sp.	18.18	—	2.12	—	—	6.45	—
Platystethus cornutus Grav.	36.36	10.64	1.41	50.00	—	—	—
Trogophleous sp.	27.27	12.77	1.76	50.00	—	11.29	14.81
Oxytelus latiusculus boehmi Bernh.	—	—	—	—	—	9.68	—
Scarabaeidae:							
Aphodius lividus Oliv.	—	—	—	—	—	16.13	—
Cucujidae:							
Monotoma picipes Herbst.	—	—	—	—	—	—	22.22
Monotoma bicolor Villa.	—	—	—	—	—	—	14.81
Elateridae:							
Drasterius bimaculatus variegatus Buys.	—	—	—	—	—	6.45	—
Dermestidae:							
Anthrenus verbaci L.	—	—	—	—	—	—	18.52
Anthrenus minir Woll.	—	—	—	—	—	—	14.81
Anthicidae:							
Anthicus crinitus Laf.	—	—	—	—	—	—	14.81
Total	100	100	100	100	—	100	100

the mixed manure in summer. Thus this manure could add another residual or hiding place for this pest.

HYMENOPTERA, COLLEMBOLA and LEPIDOPTERA seemed to be rather strays, as defined by JACOT (1940), than true manure fauna. Each of these orders composed a very small fraction of the insect farna. Hymenoptera was represented by adult species of the family Cynipidae. Lepidoptera met with was in the larval form and could not be indentified together with Collembola.

5. Arachneida

SPIDERS composed a small fraction of the total Arthropods. They were met with only in cow and mixed manures in winter at a rate of 100 and 450 specimens per cubic metre, respectively, and all belonged to the Araneomorpha-group (small spiders).

PSEUDOSCORPIONIDA : They were met with only in the mixed in winter at a rate of 5.200 specimens per cubic metre. They composed 2.60% of the total Arthropod fauna in this manure. Specimens met with belonged to the order Chelonethida Monosphyronida (Cheliferidae).

ACARINA composed not only a principal faunal fraction of the arachneid fauna, but also a large fraction of the total Arthropods. The cow manure means ranked first among the other winter or summer means (Fig. 8D), possessing 173,000 and 108.000 mites in the two periods, respectively. The mixed manure ranked second, having 143.750 specimens in winter and 57.950 in summer. Though the sheep manure mean was 55.450 specimens in winter it dropped to only 1.050 in summer. The winter ranges were from 2.000 to 215.000, 82.000 to 184.000, 17.000 to 266.000, and from 14.000 to 85.000 specimens in the sheep, cow, mixed and horse manures, respectively. The summer ranges were from nil to 10.000, from nil to 322.000, and from nil to 414.000 specimens in the sheep, cow and mixed manures, respectively.

Concerning the relative acarina percentages in total Arthropods (Table IV), the horse manure ranked first (83.60%). With the exception of the sheep manure in which mites composed 41.24% of the total Arthropods in winter and 46.66% in summer, it could be noticed that the winter percentages of cow and mixed manures

TABLE IV

Percentages of acarina in total Arthropods in various animal manures examined.

Fauna	Winter				Summer		
	Sheep	Cow	Mixed	Horse	Sheep	Cow	Mixed
Mesostigmata	0.37	16.41	6.48	2.88	11.11	7.44	3.55
Trombidiformes	40.50	45.14	58.15	—	11.11	38.09	6.40
Sarcoptiformes	0.37	7.05	7.33	80.72	24.44	3.33	58.71
Total	41.24	68.60	71.96	83.60	46.66	38.86	68.66

(68.60 and 71.96%, respectively) were higher than the summer percentages (48.86 and 68.66%, respectively). Acarina were the only arachneids met with in all manures other than the winter cow and mixed manures in which spiders and pseudoscorpions were also existing at that time.

The acarina fauna was possibly greater in magnitude than presently recorded because its number was great and smaller forms were too numerous that some of them might be overlooked during estimation. This might apply truely with the mesostigmatid Uropodina and with Tarsonemini groups of the Trombidiformes, especially members of the family Pyemotidae (Pediculoidae).

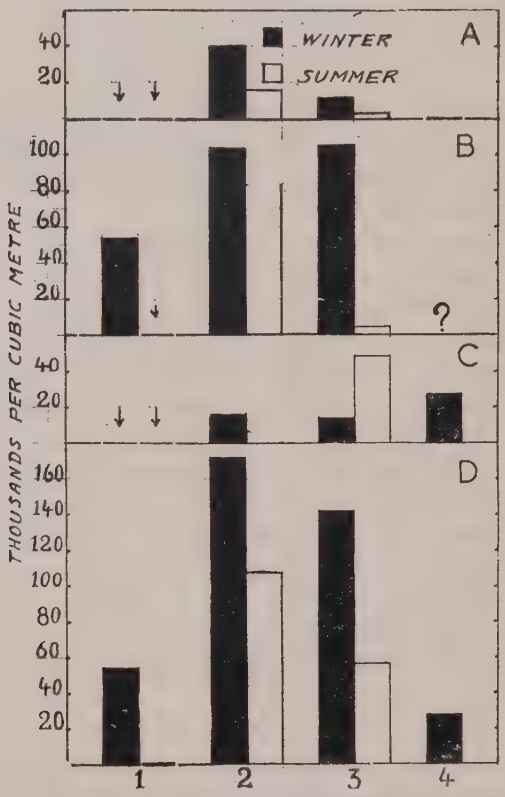

FIG. 8: Mite means per cubic metre (A, means of Mesostigmata; B, means of Trombidiformes; C, means of Sarcoptiformes; D, total mite means; 1, 2, 3 and 4: sheep, cow, mixed and horse manures, respectively).

Acarina extracted represented three main groups, as follows :

MESOSTIGMATA : The cow manure ranked first as to winter or summer mesostigmatid means (Fig. 8A). It possessed 41.550 specimens in winter and 16.450 specimens per cubic metre in summer. Mesostigmatid means were higher in winter

than in summer for every manure. The lowest mean met with was 250 specimens in the sheep manure during summer. Mesostigmatid winter ranges were from nil to 6.000 specimens in the sheep manure, from 10.400 to 12.000 in the cow manure, from 2.000 to 35.000 in the mixed manure, and from nil to 4.000 specimens in the horse manure. The summer ranges were from nil to 3.000 specimens in the sheep manure, from nil to 52.000 in the cow manure, and from nil to 18.000 specimens in the mixed manure.

The cow manure ranked first as to winter mesostigmatid relative percentages in total Arthropods (Table. IV). Mesostigmatid summer percentage of the sheep manure was, unexpectedly, higher than winter percentage while other winter percentages were higher than those of summer in every manure. Mesostigmatids as a whole composed a small fraction of the total Arthropods. They also composed a small fraction of the total acarina (Fig. 9A) as their percentages did not exceed 24% of this fauna either in winter or summer.

The mesostigmatid components were principally, Gamasids and Uropodina. The former group either composed the total mesostigmatid fauna, as was the case in sheep manure in winter and summer and the horse manure in winter, or made up more or less large fraction of this fauna in other cases.

Gamasids were represented mainly by Macrochelidae, Ascaidae, Laelaptidae, Pachylaelaptidae, Neoparasitidae, Parasitidae and Gamasolaelaptidae. Uropodina was represented by Urodiaspidae and Uropodidae.

Trombidiformes : These mites were found in enormous numbers in various manures examined except in the horse manure. The absence of them in this manure was surprising but it might be because it was treated freshly. Means per cubic metre (Fig. 8 B) were generally higher in winter than in summer. The mixed manure mean ranked first among other winter means and the cow manure mean ranked first among the summer ones. The winter ranges of Trombidiformes were from 2.000 to 251.000 specimens in the sheep manure, from 66.000 to 172.000 in the cow manure, and from 10.000 to 227.000 specimens in the mixed manure. In summer, the ranges were from nil to 2.000 specimens, from nil to 253.000, and from nil to 12.000 specimens in the sheep, cow and mixed manures respectively.

The percentages of Trombidiformes in total Arthropods (Table IV) were in general higher in winter than in summer. While these percentages exceeded 40% in the former period, they approached this percentage in the cow manure in summer and became conspicuously lower in this period in the sheep and mixed manures. As previously mentioned, trombidiform mites might be greater than presently recorded as some of them might be overlooked.

Trombidiformes composed a large fraction of the acarine fauna (Fig. 9 B), especially in winter when they made up more than 65% of the fauna. With the exception of the sheep manure in summer where Trombidiformes resembled in magnitude the Mesostigmata, the former group was superior to the latter in all other cases.

Trombidiformes met with were represented by Tarsonemini and Prostigmata, but the former group exceeded very much the latter one in all cases. Tarsonemini composed the total Trombidiformes in all manures examined in summer and in

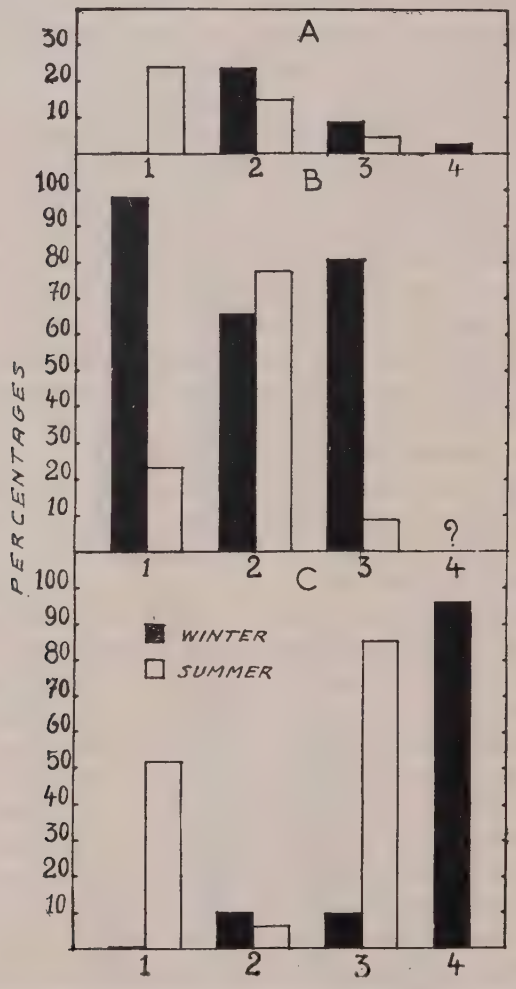

FIG. 9: Mite percentages in total mites (A, percentages of Mesostigmata; B, percentages of Trombidiformes; C, percentages of Sarcoptiformes; 1, 2, 3 and 4: sheep, cow, mixed and horse manures, respectively).

the sheep manure in winter. It made up 74.28 and 99.18 % of the total Trombidiformes in cow and mixed manures respectively in winter. Tarsonemini was represented by the Pyemotidae (Pediculoidae), Scutacaridae and Tarsonemidae, but the number belonging to the first family exceeded enormously that of the other families combined.

The prostigmatid fauna were far less in number with the exception of one case in which Pseudocheyletidae members formed 25.72% of the trombidiform fauna in the cow manure in winter. Other prostigmatid fauna were met with in the mixed manure in winter composing collectively 0.82% of the trombidiform fauna. Neverthless, this small fraction of Prostigmata included several families as Raphignathidae. Bdellidae (*Cyta* sp.), Tydeidae and Cunaxidae.

Sarcoptiformes : While the horse manure ranked first as to its highest mean (280.050 specimens) among other winter means the mixed manure mean (49.550 specimens) was the highest one in summer (Fig. 8 C). The poorest manure in the sarcoptiform fauna was the sheep manure (500 specimens in winter and 550 specimens in summer). In winter, the ranges were from nil to 7.000 specimens in the sheep manure, from 37.000 to 54.000 in the cow manure, from 2.000 to 46.000 in the mixed manure, and from 14.000 to 85.000 specimens in the horse manure. In summer, these ranges were from nil to 7.000 specimens, from nil to 84.000, and from nil to 312.000 specimens in the sheep, cow and mixed manures, respectively.

Concerning the sarcoptiform percentages in total Arthropods, more than 80% in the horse manure in winter and more than 58% in the mixed manure in summer were Sarcoptiformes (Table. IV). In the sheep manure, in summer, this percentage reached 24.44% while in other cases it dropped to from 0.37 to 7.33% of the total Arthropod fauna.

Sarcoptiforms composed 96.56% of the total mites in the horse manure in winter and 85.55% of them in the mixed manure in summer (Fig. 9 C). With the exception of these two previously mentioned percentages and the summer percentage of the sheep manure (52.38%), other percentages were low and Sarcoptiformes were very much smaller in magnitude than Trombidiformes.

Sarcoptiformes met with represented Acaridiae and Oribatei, but the former was very much greater in magnitude than the latter. With the exception of some oribatid specimens met with in the cow and mixed manures in winter, the whole sarcoptiform fauna in other cases was Acaridiae. In the cow and mixed manures in winter, oribatid fauna composed only 6.72 and 2.39%, respectively, of the sarcoptiform fauna. They belonged mainly to Hypocthoniidae. Acaridiae were represented by Acaridae (Tyroglyphidae), Glycephagidae, Winterchemidtiidae and Ensliniellidae. The first family exceeded in magnitude all members of the other families; the dominant genus being Rhizoglyphus. The various stages of *Rhizoglyphus* spp. were met with (except the egg) and many hypopial individuals were seen especially in the mixed manure in winter and summer. Six hypopa of this mite were seen in August attached to one single specimen of the beetle. *Anthicus crinitus* Laf., in the mixed manure.

C. Breeding of fauna in some samples

Three samples of the mixed manure were kept for 10 to 12 days within sieves of very fine meshes. The purpose was to identify the numerous coleopterous

larvae found in them. After extracting the fauna of these samples it was noticed that *Anthicus crinitus* Laf. was the only coleopterous beetle existing. It was found at a rate of 15.000 specimens per cubic metre. This denotes that most of the coleopterous larvae in the mixed manure in August were belonging to that species.

IV. DISCUSSION

Farmyard manure is usually applied to the cultivated land in Egypt at a rate of 100 cubic metres per acre par annum. From the faunal point of view, this amount may contain millions of Arthropod organisms which differ quantitatively and qualitatively from one kind of manure to another, according to methods of preparation and storage, and also according to the climatic factors. In the present work, various kinds of organic manure were examined in winter and summer. Samples from these manures were obtained alternatively during the two periods and the room and manure temperature degrees were recorded.

Winter means per cubic metre for total Arthropods were greater than summer means of the same manure (Fig. 1). The cow manure ranked first as to winter and summer means. This manure was partially shaded in summer when it had a comparatively high water content. Consequently, the temperature and humidity of this manure were more suitable. The sheep and mixed manures were exposed to sun in summer and their faunal means were, therefore, lower during this period.

Assuming that the number of individuals of any Arthropod group extracted from any kind of manure in the two seasons was 100 specimens, the percentages in Table V and Figures 10-12 show the effect of temperature on faunal magnitude.

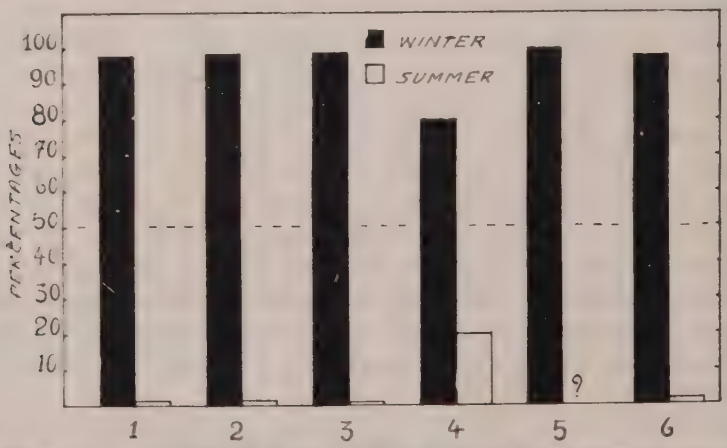

FIG. 10: Relative percentages of winter and summer means in the sheep manure, assuming that the total number of every faunal group is 100 specimens (1, total Arthropods; 2, total Insects; 3, total Diptera; 4, total Coleoptera; 5, total beetles; 6, total mites).

Concerning the sheep and mixed manures (Figs. 10 and 11) which were subjected to sun in summer, it could be noticed that their faunal percentages during this period were conspicuously lower than the winter faunal percentages. Coleoptera,

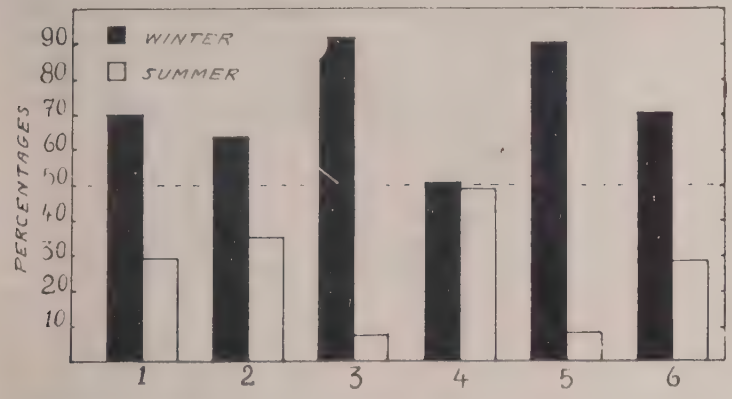

FIG. 11: Relative percentages of winter and summer means in the mixed manure assuming that the total number of every faunal group is 100 specimens (1-6, as in Figure 10).

especially in the larval stage, was not as sensitive as other fauna in this respect, as its summer percentages in the sheep and mixed manures exceeded all other percentages during this period. Beetles, on the other hand, were greater in number during

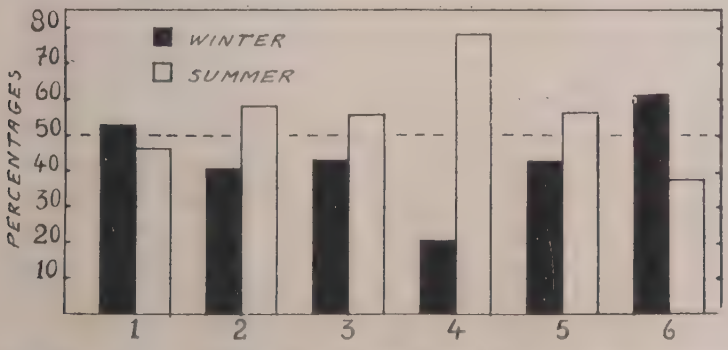

FIG. 12: Relative percentages of winter and summer means in the cow manure assuming that the total number of every faunal group is 100 specimens (1-6, as in Figure 10).

winter than during summer. Some groups of Arthropods such as Myriapoda (Diplopoda), Crustacea (sowbugs), Spiders, Pseudoscorpionida, Prostigmata and Oribatei were met with in the organic manure during winter only. In case of the cow manure, it could be noticed that winter and summer percentages fluctuated around 50% (Fig. 12). The summer percentage of coleopterous fauna, especially in the larval

TABLE V. — *Total number obtained from certain arthropod groups and their relative occurence in every manure examined.*

Fauna	Sheep manure			Cow manure			Mixed manure		
	Winter	Summer	Total	Winter	Summer	Total	Winter	Summer	Total
Number oftained									
Arthropoda	2689	45	2734	5064	4421	9485	3995	1688	5683
Insects	1580	24	1604	1588	2261	3849	951	529	1480
Diptera	1551	19	1570	1502	1943	3445	400	35	435
Dipterous larvae	1539	5	1544	1482	1853	3335	388	28	416
Coleoptera	20	5	25	83	304	387	451	432	883
Coleopterous larvae	9	5	14	36	242	278	167	405	572
Coleopterous adults	11	—	11	47	62	109	284	27	311
Mites	1109	21	1130	3474	2160	5634	2875	1159	4034
Millipedes	—	—	—	—	—	—	12	—	12
Crustacea (Sowbugs)	—	—	—	—	—	—	44	—	44
Spiders	—	—	—	2	—	2	9	—	9
Pseudoscorpionida	—	—	—	—	—	—	104	—	104
Percentages									
Arthropoda	98.35	1.65	100	53.39	46.62	100	70.30	29.70	100
Insects	98.50	1.50	100	41.26	58.74	100	64.26	35.74	100
Diptera	98.79	1.21	100	43.60	56.40	100	91.95	8.05	100
Dipterous larvae	99.68	0.32	100	44.44	55.56	100	93.27	6.73	100
Coleoptera	80.00	20.00	100	21.45	78.55	100	51.08	48.92	100
Coleopterous larvae	64.29	35.71	100	12.95	27.05	100	29.20	70.80	100
Coleopterous beetles	100.00	—	100	43.12	56.88	100	91.32	8.08	100
Mites	98.14	1.86	100	61.66	38.34	100	71.27	28.73	100
Myriapoda (Millipedes)	—	—	—	—	—	—	100.00	—	100
Crustacea (Sowbugs)	—	—	—	—	—	—	100.00	—	100
Spiders	—	—	—	100.00	—	100	100.00	—	100
Pseudoscorpionida	—	—	—	—	—	—	100.00	—	100

stage, exceeded all other winter or summer faunal percentages in this manure. To generalize, it could be mentioned that the Arthropod fauna in the organic manure during winter exceeds that in summer unless the manure is shaded during this season. In this case the fauna may be nearly similar with the exception of the coleoperous larvae which become relatively numerous in the shaded manure. Of course, these results correspond only to the surface stratum of the manure from which the samples were obtained. Deeper strata may differ greatly due to reactions taking place inside the manure.

The Arthropod fauna varied more or less from one kind of manure to another. This was possibly due to the physical and chemical properties of each manure, together with other factors as methods of preparation and period of storage. These factors open, in fact, a wide and virgin field for investigation. During sampling, it was also noticed that in the same kind of manure, even in the uniformly mixed manures as that of sheep and cow, the fauna fluctated greatly from one sample to another. The distribution of fauna in a large heap of an organic manure would solve the problem of this variation and will reveal the factors involved.

Concerning the winter manure means, it would be noticed that the cow manure ranked first as to total Arthropodes (253.200), total insects (79.400), total flies (1.000 ?), total mites (173.700) and total Mesostigmata (41.550). The mixed manure ranked first as to total Coleoptera (22.550), total coleopterous larvae and adults (8.350 and 14.200, respectively) and total Trombidiformes (116.150). Myrispoda, Crustacea and Pseudoscorpionida were only met with in the mixed manure in winter. Spiders were met with only in the cow and mixed manures in winter. The sheep manure ranked first as to total Diptera (77.550) and total dipterous larvae (76.950). The horse manure ranked first as to total Sarcoptiformes (28.050).

As to summer means, the cow manure ranked first as to total Arthropods (221.050), total insects (113.050), total Diptera (97.150), total dipterous larvae and adults (92.650 and 4.500, respectively), total beetles (3.100), total mites (108.000), total Mesostigmata (16.450) and total Trombidiformes (84.200). The mixed manure ranked first as to coleopterous larvae (20.250), total Coleoptera (21.600) and total Sarcoptiformes (49.550). The sheep manure means were in general the lowest ones in most cases due to its high temperature. It is worthy of mention that this manure ranked second to cow manure as to flies only. This confirm the remark mentioned previosly that the flies extracted by the Tullgren funnel may not show the true number of flies in the sample treated.

Table VI shows the faunal analyses of different Arthropod groups in every manure examined. Myriapoda, Crustacea, Spiders and Pseudoscorpionida composed each a very small fraction of the total Arthropod fauna. The main Arthropod groups of manure fauna were Diptera, Coleoptera and mites. In the cow, mixed and horse manures in winter and in the mixed manure in summer, the mite percentages exceeded those of the total insects in these manures. As to insects, it could be noticed that winter and summer dipterous fauna (especially the dipterous Cyclorrhaphous larvae)

TABLE VI

Percentages of different Arthropod groups in various organic animal manures.

Fauna	Winter				Summer		
	Sheep	Cow	Mixed	Horse	Sheep	Cow	Mixed
Crustucea	—	—	1.10	—	—	—	—
Myriapoda	—	—	0.30	—	—	—	—
Insecta:							
Diptera	57.68	29.66	10.01	13.81	42.22	43.95	2.07
Coleoptera	0.74	1.64	11.29	2.59	11.11	6.87	25.59
Other insects	0.33	0.06	2.50	—	—	0.32	3.68
Total insects	59.76	31.36	23.80	16.40	53.33	51.14	31.34
Arachneida:							
Spiders	—	0.04	0.23	—	—	—	—
Pseudoscorpions	—	—	2.60	—	—	—	—
Mites	41.24	68.60	71.96	83.60	46.66	48.86	68.66
Total Arachneida	41.24	68.64	74.79	83.60	46.66	48.86	68.66
Total Arthropoda	100	100	100	100	100	100	100

exceeded the coleopterous fauna with the exception of the mixed manure where the coleopterous fauna (especially the larvae) exceeded the dipterous fauna to more or less extent. Dipterous larvae both in summer and winter exceeded greatly the number of flies with the exception of sheep manure in summer where the reverse took place (Figs. 4 and 5). Beetles exceeded the larvae in winter and the reverse took place in summer (Figs., 6 and 7). Insects other than Diptera and Coleoptera were either absent or very scarce. Of these, the psocopterous fauna (*Liposcelis diverticulus*) in winter and the hemipterous fauna (*Oxycarenus hyalinipennis* Costa, nymphal stage) in summer were met with in the mixed manure with comparatively higher percentages (10.52 and 10.96%, of the total insects, respectively).

As to mites, Trombidiformes ranked first in the sheep, cow and mixed manures in winter and in the cow manure in summer (Figs. 8 and 9). Sarcoptiformes ranked first as to horse manure in winter and to mixed manure in summer. The prevailing mite group was Gamasidae in Mesostigmata, Tarsonemini (especially Pyemotidae) in Trombidiformes and Acaridiae (especially Acaridae) in Sarcoptiformes.

V. SUMMARY

1. — The mean room temperature as well as temperature means of various manures examined were recorded both in winter and summer.

2. — Winter and summer means per cubic metre for total Arthropods in various animal manures were given. These were generally higher in winter than

in summer, especially in manures exposed to sun during the latter period. Faunal fluctuations were noticeable not only from one kind of manure to another or from winter to summer, but also in the same kind of manure from sample to sample.

3. — Members of Crustacea (sowbugs) and Myriapoda (Diplopoda) were only met with in the mixed manure (manure collected from various sources) in winter. They made up a small fraction of the total arthropods in this manure.

4. — Insects composed a considerable fraction of the Arthropod fauna of every manure. Insect means for different insect groups together with their percentages either in total insects or in total Arthropods were all illustrated. Dipterous and coleopterous fauna had an outstanding position among other insect fauna. Dipterous larvae were more prevailing than adults. Coleopterous larvae were more numerous than beetles in summer but the reverse took place in winter. Coleoptera ranked first as to number of families and species obtained.

5. — Insects other than *Diptera* and *Coleoptera* were scarce. Of these, Psocopterous and hemipterous members were comparatively more prevailing.

6. — Spiders and pseudoscorpions composed collectively a small fraction of the manure arachneids. They were met with only in winter. Pseudoscorpions were comparatively more prevailing in the mixed manure than spiders.

7. — Not only were mites the principal group of the arachneid fauna in different manures, but they also composed a large fraction of the total arthropods in these manures. Mite means and percentages were given for total mites and for their components also.

8. — Comparison between winter and summer faunal structure of every manure was illustrated. The faunal analysis of every manure was also discussed.

9. — Faunal investigations of other kinds of animal manures and of organic manure in other districts are decidedly required. The distribution of fauna in a large heap of an organic manure is also needed.

VI. ACKNOWLEDGEMENTS

The writer expresses his thanks to Prof. Dr. Ahmed Sallm Hassan, professor of Economic Entomology, head of Plant Protection Departement, Faculty of Agriculture (Cairo University), for his encouragement and useful criticism. Thanks are also due to Mr. A. Alfieri, General Secretary of Entomological Society of Egypt, for the identification of beetles mentioned in this paper.

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COMPARATIVE MORPHOLOGY OF SOME DYNASTID LARVAE INJURIOUS TO AGRICULTURE IN EGYPT [1]

[*Coleoptera* : *Scarabaeidae*]

(with 32 Text-Figures)

by SADEK I. BISHARA, B.SC.

INTRODUCTION

Scarabaeid larvae or "white grubs" are soil insects of major economic importance in many parts of the world. In Egypt, FAIRMAIRE (1893) recorded *Heteronychus cribratellus* Fairm. (*Pentodon bispinosus* Küst.) attacking sugar-cane and maize, and WILLCOCKS (1925) found *Pentodon dispar* Baudi (=*Pentodon bispinosus* Kust.) and *Heteronychus* species as injuring sugar-cane and maize. The damage of these insects has extended to many other crops such as: wheat, cotton and clover; vegetables such as cabbage, cauliflower, cow-pea, artichoke and vegetable marrow; nursery plants and young wood trees; fruit trees such as pear, apple, mango and loquat; melons; garden plants such as *Zinnia elegans*; lawns and golf-courses.

Unfortunately, damage caused by these pests has not been fully estimated. Therefore, it has been found advisable to undertake their biological study, which may help in reaching their effective control.

The present work deals with the identification of the structural differences existing between the third instar larvae of *Pentodon bispinosus* Kust., *Temnorrhynchus baal* Reiche, and *Phyllognathus excavatus* Forst. (=*silenus* F.), respectively.

The need for such a study has been emphasized by WILLCOCKS (1925) who has given, however, ALFIERI's key for identifying the Egyptian hard-back beetles belonging to the subfamily Dynastidae.

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(1) This work has been carried out under the supervision of Prof. DR. MAHMOUD HAFEZ, head of the Entomology Department, Faculty of Science, Cairo University.

From our rearing experiments of larvae, collected from various parts of Egypt, and the available adults attracted to light-traps (with ultra-violet fluorescent lamps) set up in some different localities, it appeared that the three following species (belonging to three genera) are mostly common. These differ in their local distribution as follows :

Pentodon bispinosus Kust. (=*dispar* Baudi) is widely distributed in Lower and Upper-Egypt and even in the oases, but is less common near the Mediterranean sea-coast.

Temnorrhynchus baal Reiche, is common along the Mediterranean sea-coast east of Alexandria to Abukir and southwards. It occurs also in Sharkia, Qualiubia, Giza and Gerga regions.

Phyllognathus excavatus Forst. (=*silenus* F.) which is the only species that exists in the narrow poorly cultivated belt along the Mediterranean sea-coast western of Alexandria, passing by Borg-el-Arab, Marsa Martuh and Sallum. It occurs also in North Sinai. Very few individuals were met with near Cairo.

These Dynastids are also known in nearly all the countries of the Mediterranean region, e.g. South France, Spain, Balearic Islands, Sardinia, Sicily, Greece, Cyprus, North Africa, Egypt, Mesopotamia, Syria and Asia Minor.

DESCRIPTION OF THIRD LARVAL STAGE OF *PENTODON BISPINOSUS* KUST.

The mid-dorsal length of the larva, measured from anterior margin of frons to anus, is 7-8 cm.; the average extreme width of the cranium (Fig. 1) measures 7.5 mm.

The term cranium is used here for the head-capsule formed by the two immovable parts, viz. the frons and the epicranium. The cranium is narrower than the prothorax (the width of the prothorax being about 11 mm. and the mesothorax about 12 mm.); broader than long, about 5mm. in length; its surface is smooth, shining and brownish-yellow in coulour, with the anterior wide area of frons pitted with numerous punctures. Clypeo-frontal suture (*clfs*) well marked; frontal sutures (*fs*) (or epicranial arms, auct.) fine, whitish, anteriorly convex toward the outside, posteriorly slightly convex, meeting considerably in front of hind margin of head forming an angle of about 85°. Epicranial suture (*es*) (or epicranial stem, auct.) about one-half the length of one of the frontal sutures, and well differentiated into the following three parts :

(1) The anterior two-fifths fine, whitish like the frontal sutures which meet at its anterior end.

(2) The second part is about one-half of its whole length; it is dark in colour, almost black, somewhat thick and a little deeper than the anterior part. The adjacent regions of the epicranium are dark in colour and slightly elevated along this part having the appearance of a biconvex lens.

(3) The third part is fine, whitish and very short comparatively.

The head capsule is furnished with many setae; the anterior pitted, wide region of the frons is covered with two groups each of about 20 moderately long setae (*l*) arranged in the form of two upturned triangles; a single seta (*m*) opposite the constriction of each frontal suture, and a single seta (*n*) near the posterior part of each frontal suture before they meet; six long setae (*o*) are at the base of each frontal condyle in a curved line; between the frontal condyle and the torulus, three long setae (*p*) exist.

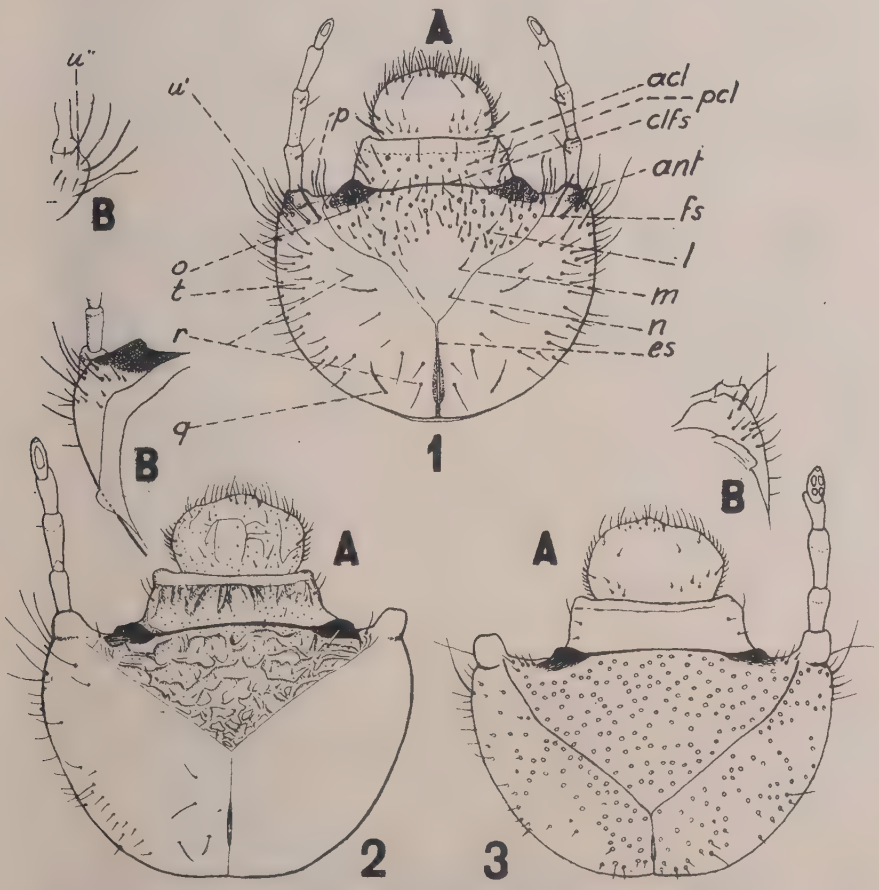

FIG. 1: A, Head of *Pentodon bispinosus* Küst., dorsal view (*acl*, ante-clypeus; *ant*, torulus; *clfs*, clypeo-frontal suture; *es*, epicranial suture; *fs*, frontal suture; *pcl*, post-clypeus; *l*, *m*, *n*, *o*, setae on frons; *q*, *r*, *t*, *u'*, setae on epicranium; *p*, setae between frontal condyle and torulus); B, *u"*, setae on ventral side of epicranium. — FIG. 2: A, Head of *Temnorrhynchus baal* Reiche, dorsal view; B, setae on ventral side of epicranium. — FIG. 3: A, Head of *Phyllognathus excavatus* Forst , dorsal view; B, setae on ventral side of epicranium.

The setae on the epicranium are arranged on each side as follows : a single seta (*q*) near the hind margin of the head somewhat far from the epicranial suture; a series of about seven long setae (*r*) in a slightly curved line beginning near the posterior part of the epicranial suture and ending near the constriction of the frontal suture; a great number of moderately long setae (*t*) in the form of two or three long series parallel to the lateral outer margin of the epicranium; between the setae (*r*) and (*t*) an elliptical region devoid of setae is found; the anterior part of the epicranium is provided with some long setae; partly encircling the ring-shaped support of the antenna (or torulus) (*ant*), a group of about twelve long setae and some short ones (*u*' and *u*'', Fig. 1) are present, the latter (*u*'') in a patch on the ventral side of the cranium extending backwards (Fig. 1, B).

Clypeus (Fig. 1, A) : sub-trapezoidal, divided into an anterior whitish, naked part, ante-clypeus (*acl*) and a larger darkly sclerotized, post-clypeus (*pcl*), the latter carrying setae, and pitted with numerous punctures; each side of the post-clypeus with three anterior and one posterior lateral long setae, and a single seta near the sagittal line.

Labrum (Figs. 1 and 11) : somewhat longer and slightly narrower than the clypeus, angular at the middle of each lateral outline and apically somewhat

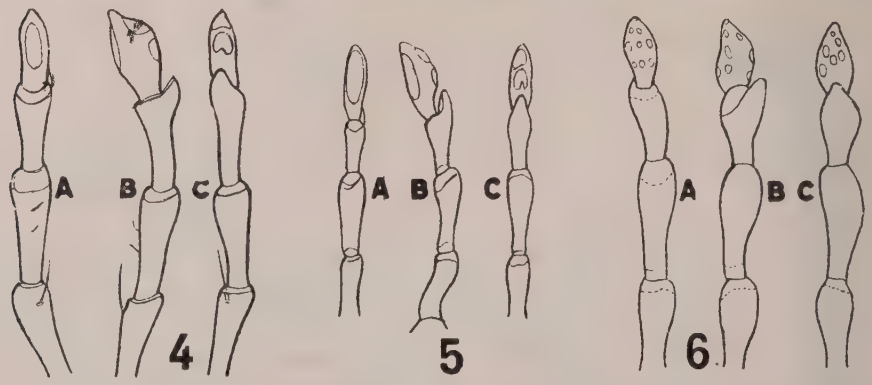

Fig. 4: Antenna of *Pentodon bispinosus* Küst., third instar larva (A, dorsal view; B, lateral view; C, ventral view). — Fig 5: Antenna of *Temnorrhynchus baal* Reiche (A, dorsal view; B, lateral view; C, ventral view). — Fig. 6: Antenna of *Phyllognathus excavatus* Forst. (A, dorsal view; B, lateral view; C, ventral view).

projecting. On the right side of this apical projection, there is a small dark depression, corresponding to the epizygum of the epipharynx. Surface of labrum smooth but wrinkled and bearing setae distributed as follows : on apical projection two anterior moderately long stiff setae (*a*) and five longer ones (*b*) in a transverse curved series, partly encircling (*a*); three long stiff setae (*c*) in the lateral margin itself on each side of the apical projection; a single long stiff seta (*d*) on the left side posterior to (*c*),

and two similar ones (*e*) on the right side of the dark depression near the lateral margin and posterior to (*c*); three long setae (*f*) on each side of the lateral margin of labrum, the first one near the apical region, the second one opposite the angular part and the third one near the posterior part; near the sagittal line on each side with one anterior long seta (*g*) and a group of six posterior ones, three long and three short.

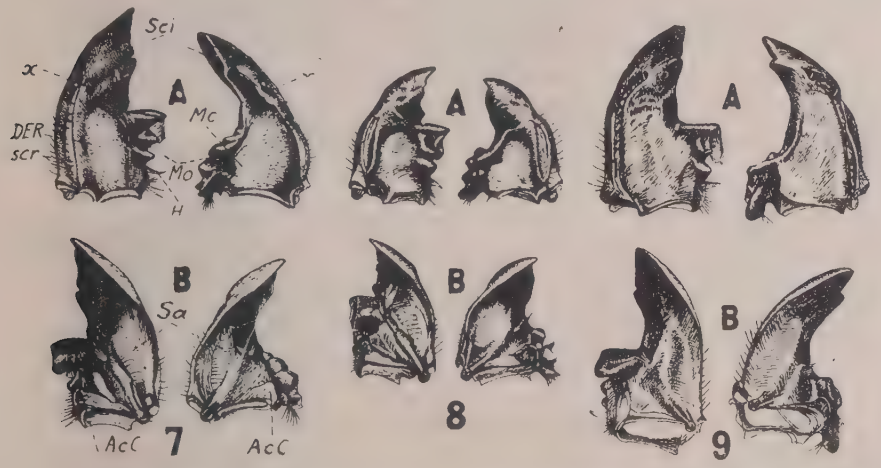

FIG 7: Mandibles of third instar larva of *Pentodon bispinosus* (A, dorsal view: *der*, dorso-exterior region; *H*, hamus; *Mc*, manducatorial part; *Mo*, molar structure; *Sci*, scissorial part; *Scr*, scrobis; *x*, dorsal sensorial groove. — B, ventral view: *AcC*, accessory ventral condyle; *Sa*, stridulatory area). — FIG. 8: Mandibles of third instar larva of *Temnorrhynchus baal* (A, dorsal view; B, ventral view). — FIG. 9: Mandibles of third instar larva of *Phyllognathus excavatus* (A. dorsal view; B, ventral view).

ANTENNA (Figs. 1 and 4) : the left antenna is about as long as the right mandible; the right antenna is slightly shorter; slender with four movable articles, carried by a connate antennal support or torulus (*ant*); sub-apical article ventrally produced into a conical process; apical article sub-elliptical, somewhat asymmetrical, distally slightly constricted and ventrally angular at the middle, furnished dorsally with one semi-transparent sensory spot (sensilla placodea), oval in shape and nearly half the length of the apical segment, and ventrally with two smaller ones, the distal one nearly semi-circular and the proximal nearly circular with a small basal depression. First, second and third articles rather slender; first and second of about equal length, the second somewhat longer; the third or subapical smaller than the first, but longer or equal to the apical. The basal article has one long seta dorsally, the second segment has two dorsal short ones, and the torulus has several setae.

MANDIBLE (Figs. 7 and 10) : the left mandible is longer than the right one, both being smaller in length than the cranium and generally as light coloured, but distally each mandible with black scissorial part (*Sci*), and proximally with black manducatorial part (*Mc*), black mandibular fossa, black condyle and dark accessory ventral condyle (*Ac C*). Scissorial part, with a slightly wavy almost straight cutting edge, which posteriorly is limited by a notch whose hind wall is produced into a small tooth. On dorsal side, scissorial part marked by one large oval sensorial groove (*x*), with one seta at its anterior end; edge of scissorial part behind the notch smooth. Manducatorial part (*Mc*), with a molar structure. Molar structures different and asymmetrical on right and left mandibles. Molar structure of right mandible (Fig. 7 and 10A), trilobed with the lobes increasing in size posteriorly. Last lobe or calx (*Cx*) is divided by a longitudinal ridge into an inner oblique hollow plate, and an

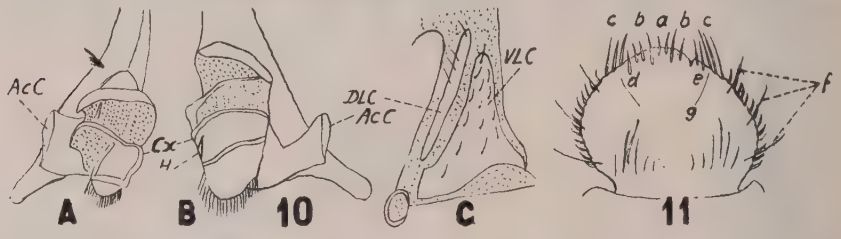

FIG. 10: Mandibles of *Pentodon bispinosus* larva (A, right mandible, front view: *AcC*, accessory ventral condyle; *Cx*, calx. — B, left mandible, front view: *H*, hamus. —*C*, scrobis of right mandible: *DLC*, dorso-lateral carina; *VLC*, ventro-lateral carina). — FIG. 11: Labrum of *Pentodon bispinosus*, dorsal view; (*a-g*, setae on labrum).

outer rectangular plate with a concave face and a basal rounded edge. Molar structure of left mandible (Fig. 7 and 10B) projecting anteriorly and receiding posteriorly, trilobed, with anterior lobe shielding the lower posterior smaller lobes; calx (*Cx*) poorly developed having a sub-trapezoidal face divided by a transverse oblique ridge into two concave regions, the posterior region having a narrow rounded end, the anterior one characterised by a slender, tapering and pale projection termed hamus (*H*). A well developed brush of long bristles is found at the bases of both right and left molar parts. Ventral side of each mandible provided with an accessory ventral condyle (*Ac C*), formed by a marginal projection between calx and the mandibular condyle, articulating with the hypopharyngeal sclerite, and co-ordinating the protrusion and retraction of hypopharynx with the opening and closing of the mandibles. Dorsal surface of each mandible with a few setae at the molar structure about seven in a longitudinal series. Dorso-exterior regions of mandibles "DER" without punctures and setae. Laterally and exteriorly each mandible with elongate sub-triangular and somewhat sunken surface forming a scrobis (Figs. 7 and 10C, *Scr*), which is divided by a dark longitudinal septum into two light coloured low carinae. Dorsolateral carina (*DLC*) starting near the dorsal sensorial groove of the

scissorial part, elongate and marked by one long seta at its distal end, and three rather short setae in a longitudinal row along its anterior half. Ventro-lateral carina (*VLC*) sub-triangular, shorter than the dorso-lateral one, and furnished with about fourteen, rather long, scattered setae. On ventral side of each mandible, opposite the first lobe of the molar structure, a patch of about ten setae of different lengths arise from a single pit and appear as a single, long and thick seta when moist. Between this pit and the outer margin of each mandible, appears a series of minute ridges, transversely arranged. The longest ridges are the median ones. The others become gradually shorter to give the whole a uniform oval appearance. These constitute a part of the stridulatory organ (Fig. 7 B, *Sa*).

Maxillary Lobes (Figs. 12 and 15) : lacinia and galea, fused proximally into a single structure but distally free. Ventral surface exclusively formed by galea;

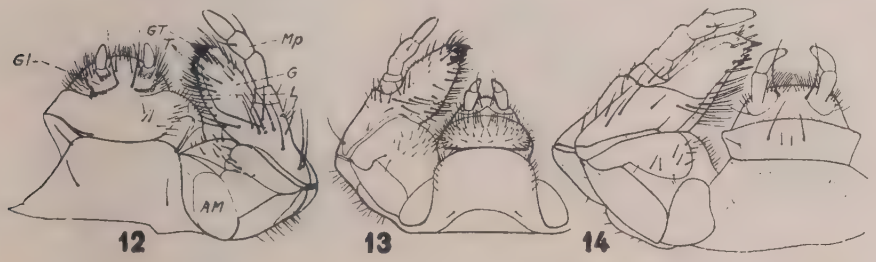

Fig. 12: Maxilla and labium of *Pentodon bispinosus*, ventral view (*Am*, maxillary articulating area; *Gl*, glossa; *G*, galea; *GT*, galeal tooth; *L*, lacinia; *LT*, lacinial teeth; *Mp*, maxillary palp). — Fig. 13: Maxilla and labium of *Temnorrhynchus baal*, ventral view. — Fig. 14: Maxilla and labium of *Phyllognathus excavatus*, ventral view).

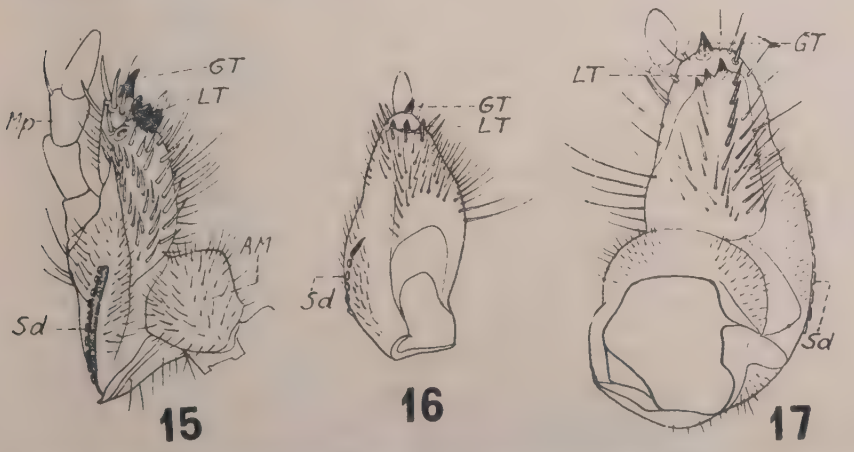

Fig. 15: Maxilla of *Pentodon bispinosus*, front view (*Sd*, stridulatory teeth; other terms as in Figure 12 . — Fig. 16: Maxilla of *Temnorrhynchus baal*, front view (terms as in Figure 12). — Fig. 17: Maxilla of *Phyllognathus excavatus*, front view.

dorsal surface formed by both galea and lacinia (*G* and *L*); galea ending in a single strong tooth (Fig. 15, *GT*), lacinia in three basally fused, strong teeth (Fig. 15, *LT*), decreasing gradually in size and obliquely beset. Galea and lacinia covered with many long stiff setae, but the anterior part of galea having fine long setae. Stipes, on dorsal side with a longitudinal row of ten oval, blunt stridulatory teeth (Fig. 15, *Sd*) which by movements of the mouth-parts, rasp against the ridges of the mandibles. Maxillary palpus (Figs. 12 and 15, *Mp*) projecting beyond galea, with four articles, first segment as half the length of the second; the third article as nearly long as the second; the apical segment sub-oval and as nearly long as the first and third articles together. Sub-apical article with two setae. Maxillary articulating area (*AM*) large and setose.

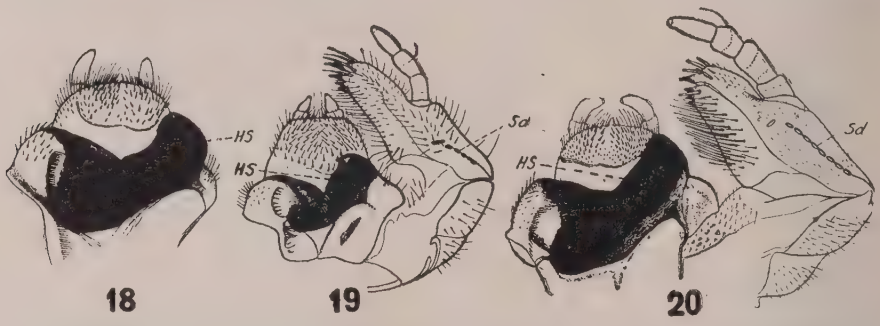

FIG. 18: Labium and hypopharynx of *Pentodon bispinosus* (*HS*, hypopharyngeal sclerite). — FIG. 19: Maxilla, labium and hypopharynx of *Temnorrhynchus baal*, dorsal view (*HS*, hypopharyngeal sclerite; *Sd*, stridulatory teeth). — FIG. 20: Maxilla and hypopharynx of *Phyllognathus excavatus*, dorsal view.

HYPOPHARYNX (Figs. 12 and 18) : with large rounded glossa "*Gl*" beset with short, strong setae posteriorly, and long fine setae anteriorly. Hypopharyngeal sclerite (*HS*) blackish, strong, with several tufts of setae, and a fossa on each side. for the accessory ventral condyle of the mandible.

LABIAL PALPUS (Figs 12 and 18) : with two articles, the apical one longer than the basal one, both are devoid of setae.

EPIPHARYNX (Fig. 21) : situated under the labrum and clypeus, continued into the dorsal wall of the pharynx, with boundary line toward pharynx marked by the transverse, curved crepis (*Crep*). Apical region (*AR*) anterior to zygum (*Z*), beset with numerous strong spine-like setae; plegmatia and proplegmatia absent. Acanthoparia (*Ap*) with coarse, cultriform setae, about thirteen in number; gymnoparia "Gp" present; chaetoparia (*Cp*) large with setae of various sizes. Haptomeral region with distinct epizygum (*EZ*), between zygum and anterior margin of epipharynx. Zygum is a dark and heavily sclerotized convex plate, produced posteriorly into two distinct teeth, which is a useful character in distinguishing *Pentodon*

bispinosus Küst. from other native Scarabaeidae. Pedium (*Ped*) longer than wide. Laeotorma (*Lt*), with tapering, anteriorly curved end, and an epitormal process (*epit*); dexiotorma (*Dxt*), almost straight and tapering. Crepis (*Crep*), formed of

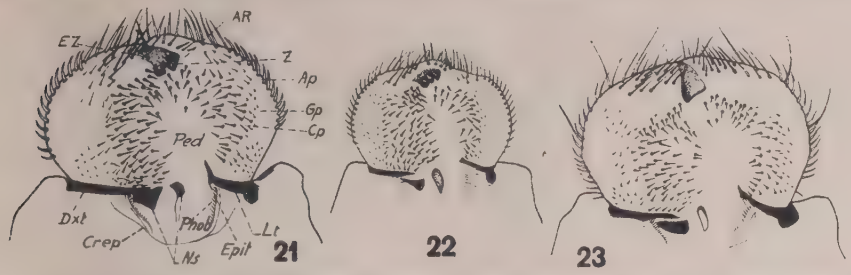

Fig 21: Epipharynx of *Pentodon bispinosus* (*AR*, apical region; *Ap*, acanthoparia; *Cp*, chaetoparia; *Crep*, crepis; *Dxt*, dexiotorma; *Epit*, epitormal process; *Ez*, epizygum; *Gp*, gymnoparia; *Lt*, laeotorma; *Ns*, nesium; *Ped*, pedium; *Phob*, phoba-like hairs; *Z*, gygum). — Fig. 22: Epipharynx of *Temnorrhynchus baal*. — Fig. 23: Epipharynx of *Phyllognathus excavatus*.

a left nearly triangular, elongate, thinly sclerotized plate, and a very thin curved continuation to the right, smaller plate. About twenty phoba-like hairs (*Phob*) in a longitudinal series arranged in front of left part of crepis and a smaller number of

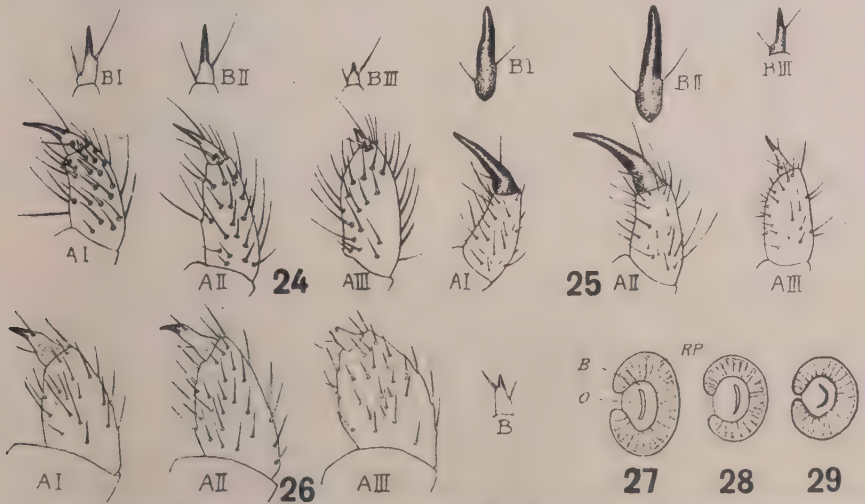

Fig. 24: AI-AIII, tibio-tarsus and claw of first, second and third legs of *Pentodon bispinosus*, lateral view; BI-BIII, claws, anterior view. — Fig. 25: AI-AIII, tibio-tarsus and claw of first, second and third legs of *Temnorrhynchus baal*, lateral view; BI-BIII, claws, anterior view. — Fig. 26: AI-AIII, tibio-tarsus and claw of first, second and third legs of *Phyllognathus excavatus*, lateral view; B, claws, anterior view. — Fig. 27: Spiracle of *Pentodon bispinosus* (*B*, bulla; *O*, orifice; *RP*, respiratory plate). — Fig. 28: Spiracle of *Temnorrhynchus baal*. — Fig. 29: Spiracle of *Phyllognathus excavatus*.

shorter hairs in front of right part; two triangular nesia (*Ns*) present, the bigger one placed posterior to inner end of dexiotorma, the other almost in the middle line of epipharynx, and more thinly sclerotized.

Legs (Fig. 24) : gradually and slightly increasing in length from first to third, beset with long yellowish-brown setae, particularly dense on posterior surfaces of its segments. Claws or tarsunguli (I, II, III, Fig. 24), unequal in length and different in shape. On first and second legs, claws somewhat longer than half the length of apical segment (or tibiotarsus), enlarged at base, tapering gradually toward the pointed end. Claw of third leg, with distinct base but very short distal part. Base of each claw, light in colour, armed on each lateral side with a single long spine-like seta; these two setae are unequal in length and one is beset anterior to the other. The distal part of each claw, needle-shaped, dark in colour and round in cross section.

Body : typical scarabaeiform, distinctly C-shaped, subcylindrical and fleshy. Body covering slightly sclerotized, and general colour creamy-white with shades of grey. Caudal end dark grey, due to accumulation of faeces within, which can be seen through the semi-transparent integument. Body segments with dorsal annulets. Prothorax with a thinly sclerotized elongate plate bearing about five setae.

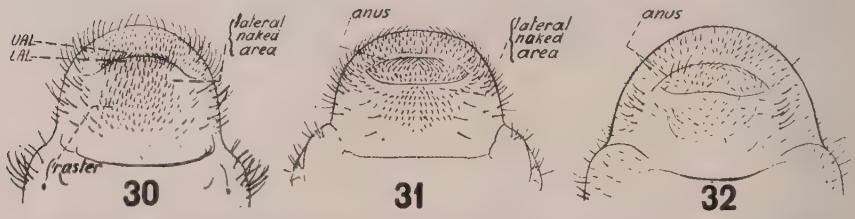

Fig. 30: Raster of *Pentodon bispinosus* (*UAL*, upper anal lip; *LAL*, lower anal lip). — Fig 31: Raster of *Temnorrhynchus baal.* — Fig. 32: Raster of *Phyllognathus excavatus.*

Anus (Fig. 30) transverse, arcuate. Upper anal lip (*UAL*) covered with numerous small, stiff and pointed setulae; lower anal lip (*LAL*) covered with moderately long stiff setae, with curved edges, interspersed among them a single series of fine long setae. On the lateral sides of the anal slit, many long fine setae are scattered.

Raster (Fig. 30) : numerous coarse, rather long, scattered, brown, hooked spines; laterally two small naked areas are distinguishable; no pallidia.

Spiracles (Fig. 27) : with strongly curved respiratory plate (*RP*); bulla (*B*) almost circular, spiracular orifice (or stoma) (*O*) arcuate. Spiracles on prothorax and the first eight abdominal segments. Prothoracic spiracle, bigger in size than any abdominal one. The first five abdominal spiracles nearly equal in size, and bigger than sixth and seventh; eighth is the smallest one. The concavity of the thoracic respiratory plate facing posteriorly; that of the abdominal respiratory plates facing anteriorly.

DIFFERENTIATING CHARACTERS OF THE THREE SCARABAEID TYPES CONCERNED

Claws

Pentodon bispinosus Küst. (Fig. 24) : On first and second legs, equal or somewhat longer than half the length of apical article or (tibiotarsus); enlarged at base, tapering gradually toward the pointed end. Distal part, dark in colour, needle-shaped and round in cross section.

Temnorrhynchus baal Reiche (Fig. 25) : Claws on first and second legs, as long as apical article, with flat posterior surface, and rounded anterior surface, black in colour and distinctly wide in front view.

Phyllognathus excavatus Forst. (Fig. 26) : Claws on first and second legs, about one-third the length of tibio-tarsus, enlarged at base, with short, tapering and curved distal part. Anterior margin of claw concave.

Raster

Pentodon bispinosus Küst. (Fig. 30) : Numerous coarse, rather long, scattered, brown, hooked spines; laterally two small naked areas are distinguishable; no pallidia; long fine setae around anal region.

Temnorrhynchus baas Reiche (Fig. 31) : The lateral naked areas are transversely elongated, and nearly meet each other at the sagittal line; no pallidia. Long fine setae around anal region.

Phyllognathus excavatus Forst. (Fig. 32) : Numerous, small, stiff, curved setulae; few long stiff setae on lower anal lip; small setulae on upper anal lip; laterally very fine long setae. No hooked spines as in case of *Pentodon* and *Temnorrhynchus*.

Cranium

Pentodon bispinosus Küst. (Fig. 1) : Beset with numerous long fine setae; anterior part of frons pitted with numerous punctures, with two groups each of about twenty moderately long setae, arranged in the form of two upturned triangles. Frontal suture anteriorly convex and posteriorly slightly convex. Angle formed by the two frontal sutures equals about 85 degrees. Width of cranium about 7.5 mm., and yellowish-brown in colour.

Temnorrhynchus baal Reiche (Fig. 2) : Anterior part of frons with three curved, transverse grooves; the third one is incomplete in the middle. Each groove with a single series of few small fine setae. Frontal suture almost straight along its whole length, with a gently curved anterior end. Angle formed by two frontal sutures equals about 95 degrees. Width of cranium 5.5 mm., and brownish-orange in colour.

Phyllognathus excavatus Forst. (Fig. 3) : Setae on cranium few; surface pitted with numerous punctures; frontal suture anteriorly convex, posteriorly nearly

straight. Angle formed by the two frontal sutures equals about 92 degrees. Width of cranium 7.5 mm., and reddish-brown in colour.

Length

Pentodon bispinosus Küst. : Mid-dorsal length of larva measured from anterior margin of frons till anus, 7-8 cm.

Temnorrhynchus baal Reiche : length 5-6 cm.

Phyllognathus excavatus Forst. : length 7-8 cm.

Antenna

Pentodon bispinosus Küst. (Fig. 4) : Apical article furnished with a single sensilla placodea dorsally, and two smaller ventral ones; no apical sensory membrane. The dorsal sensilla placodea is oval in shape and nearly as half the length of the apical article. The subapical is equal in length or slightly longer than the apical one.

Temnorrhynchus baal Reiche (Fig. 5) : One dorsal and two ventral sensillae placodeae present, and an apical sensory membrane furnished with minute sensorial pegs. The dorsal sensilla placodea is oval in shape and in length it measures more than half the length of the apical article. The subapical article is much smaller in length than the apical one, in contrast with that of *Pentodon bispinosus* Küst.

Phyllognathus excavatus Forst. (Fig. 6) : Apical article furnished with about fifteen small sensory spots, particularly dense on the dorsal and ventral surfaces; an apical sensory spot present; subapical article as long as apical one or may be a little bit longer.

Epipharynx

Pentodon bispinosus Küst. (Fig. 21) : Zygum with two distinct posterior teeth; acanthoparia with thirteen coarse cultriform setae; laeotorma with an epitormal process.

Temnorrhynchus baal Reiche (Fig. 22) : Zygum with three distinct teeth; acanthoparia with fifteen setae. Inner end of laeotorma, slightly diverging.

Phyllognathus excavatus Forst. (Fig. 23) : Zygum is a big sclerotized plate without any differentiation into distintc teeth; acanthoparia with fifteen setae.

Maxilla

Pentodon bispinosus Küst. (Fig. 15) : The three lacinial teeth are obliquely placed, gradually decreasing in size and basally fused; stridulatory teeth blunt, oval and ten in number. Maxillary palp without apical whitish membrane.

Temnorrhynchus baal Reiche (Fig. 16) : The three lacinial teeth are equal in size, do not meet at their bases, somewhat far from each other and inverted in a horizontal line. Stridulatory teeth six blunt oval ones; maxillary palp with apical whitish membrane.

Phyllognathus excavatus Forst. (Fig. 17) : The three lacinial teeth are gradually decreasing in size, obliquely placed with their bases touching. Stridulatory teeth, blunt, oval and ten in number; maxillary palp with apical whitish membrane.

Labial palp

Pentodon bispinosus Küst. (Fig. 12) : Moderate in length.

Temnorrhyncus baal Reiche (Fig. 13) : Short comparatively, apically with a whitish membrane.

Phyllognathus excavatus Forst. (Fig. 14) : Long comparatively and apically with a whitish membrane.

Spiracles

Pentodon bispinosus Küst (Fig. 27): The respiratory plate is of moderate thickness in relation to its size; its concavity is not narrow.

Temnorrhynchus baal Reiche (Fig. 28) : The respiratory plate is comparatively thin; its concavity is wide.

Phyllognathus excavatus Forst. (Fig. 29) : The respiratory plate is fairly thick in relation to its size; its concavity is very narrow, the two ends nearly touching.

Mandibles

Pentodon bispinosus Küst. (Fig. 7) : With one dorsal sensorial groove on each scissorial part

Temnorrhynchus baal Reiche (Fig. 8) : With four dorsal smaller sensorial grooves; the mandibles are comparatively small.

Phyllognathus excavatus Forst. (Fig. 9) : With one dorsal sensorial groove on each scissorial part.

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DAS MÄNNCHEN VON *ACETROPIS SINUATA* E. WAGNER

[*Hemiptera-Heteroptera* : *Miridae*]

(mit 10 Abbildungen)

von EDUARD WAGNER, Hamburg.

Beschreibung : Gestalt lang und schmal, wie bei *A. gimmerthali* Fl. Hell graugelblich bis gelbweiss, mit undeutlicher brauner Zeichnung. Fühler und Beine mit hellgelben, kurzen Borsten besetzt.

Kopf (Fig. 1) kurz und breit, mit schmaler brauner Mittellinie und jederseits einem braunem Fleck hinten am Auge. Scheitel 2.35-2.45 × so breit wie das runde, braune Auge. Fühlerhöcker braun. 1. Fühlerglied graubraun, schlank, etwas kürzer als der Kopf breit ist; 2. Glied stabförming, hellgelb. Spitze bräunlich, 1.8 × so lang wie das Pronotum breit ist; das 3. Glied kurz, kaum 0.3 × so lang wie das 2. und fast 1.5 × so lang wie das 4., die beiden Endglieder braun.

Pronotum (Fig. 1) kurz und breit, seine Seiten deutlich geschweift. Mittelkiel zwischen den Schwielen deutlich und dick, nach hinten schmaler und undeutlicher werdend, aber bis nahe an den Hinterrand reichend. Hinterrand mit schmalem, blattartigem, aufgebogenem Rande, bisweilen in der Mitte geschweift. Beiderseits neben dem Seitenrande eine braune Längsbinde, auch der Mittelkiel von 2 schmalen braunen Längsstreifen eingefasst. Scutellum in der Regel einfarbig hell. Halbdecken mit kielartig erhabenen Adern, zwischen den Adern oft dunkle Längsflecke. Membran stets voll entwickelt, die grosse Zelle reicht fast bis zum Ende der Membran.

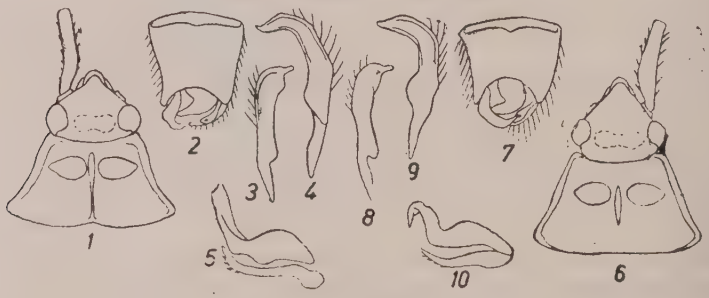
Unterseite hell. Beine gelblich, das 2. und 3. Tarsenglied schwarzbraun. An den Hintertarsen ist das 1. Glied deutlich dicker aber kürzer als das 2. und 3. zusammen.

Genitalsegment des Männchens (Fig. 2) trapezförmig, Genitalöffnung gross, jederseits neben ihr ein stumpfer Fortsatz. Rechter Paramer (Fig. 3) lang und schlank, Hypophysis kurz und abgerundet. Linker Paramer (Fig. 4) sichelförmig, distal spitz, Hypophysis mit feiner, aufwärts gerichteter Spitze. Vesika des Penis mit 2 Chitinstäben (Fig. 5): der ventrale Stab ist kleiner, distal gekrümmt und sein

Aussenrand vor der Spitze grob gezähnt; der dorsale Stab ist grösser, proximal sehr dick, in der Mitte eingeschnürt und distal aufwärts gekrümmt; der aufwärts gerichtete Teil ist parallelseitig, gerade und distal stumpf.

Länge : Männchen = 5.1-5.8 mm., Breite des Pronotum = 1.25-1.40 mm.

Das Männchen von *A. sinuata* E. Wagner. ist demjenigen von *A. gimmerthali* Fl. sehr ähnlich. Wie das Wiebchen aber unterscheidet es sich von dieser Art durch die stark geschweiften Pronotumseiten. Bei *A. gimmerthali* (Fig. 6) sind diese zwar ebenfalls etwas geschweift, aber die Schweifung ist viel geringer und fehlt oft völlig. Bei *A. gimmerthali* ist der Mittelkiel nur neben den Schwielen und kurz



Acetropis, Männchen :

Fig. 1-5 = *A. sinuata* E. Wagn. — Fig. 6-10 = *A. gimmerthali* Fl. — 1 + 6 = Kopf und Pronotum von oben (18 ×) 2 + 7 = Genitalsegment von oben (18 ×) 3 + 8 = rechtre Paramer dorsal (48 ×) 4 + 9 = linker Paramer dorsal (48 ×) 5 + 10 = Chitinstäbe der Vesika seitlich (48 ×).

dahinter zu erkennen. Der Kopf ist etwas länger (Fig. 6), der Scheitel 2.5-2,6 × so breit wie das kleinere Auge. Die Längenverhältnisse der Fühlerglieder schwanken so stark, dass sie als Trennungsmerkmal kaum geeigne sind, im Mittelwert aber doch Unterschiede zeigen. So ist das 2. Glied im Mittel nur 1.5-1.7 × so lang wie das Pronotum breit ist, das 1. Glied erscheint viel dicker, ist aber von etwa der gleichen Länge. Im Bau der Genitalien dagegen zeigen sich brauchbar Unterschiede. Das Genitalsegment des Männchens (Fig. 7) ist kürzer und breiter, ber linke Paramer (Fig. 9) ist kürzer und picker, die Hypophysis gerade, breiter und stumpfer. Die Chitinstäbe der Vesika unterscheiden sich stark (Fig. 10); der ventrale Stab ist kürzer und spitzer, distal fein behaart; der dorsale Stab ist schlanker ,der aufwärts gerichtete Teil stark gekrümmt, spitz und nicht parallelseitig.

A. sinuata E. Wgn. wurde vom Verfasser (E. Wagner: Neue Mirdenarten aus Nordafrika (*Bull. Soc. Fouad I Entom.*, XXV, 1951: 145-148)) nach einem einzelnen Weibchen aus Marokko beschrieben. Seitdem lagen mir weitere Exeplare aus Algier: Boufarik (3 Weibchen, A. Théry) und aus Bulgarien: Petric 16.5.55 (Zahlreiche Männchen und Weibchen, M. Josifov) vor. Die letzte Ausbeute enthielt zum ersten Male Männchen der Art. Dadurch wurde es möglich, auch das Männchen zu

untersuchen und zu beschreiben. Seine Untersuchung aber zeigte, dass es sich hier um eine gut getrennte Art handelt.

Ich untersuchte 4 Männchen aus Bulgarien (l.c.). ALLOTYPOID und PARATYPOIDE in meiner Sammlung.

Herrn Dr. M. JOSIFOV, Sofia, der mir das Material zur Verfügung stellte, sei auch an dieser Stelle bestens gedankt.

THE ANOPHELINE MOSQUITOES OF NORTHERN SYRIA

(with Text-Figures and Tables)

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This paper represents the results of a survey made by the author for the study of the distribution and biology of the anopheline mosquitoes present in northern Syria, while being delegated by the World Health Organization International Team for the malaria control demonstration center to Syria. The survey started in March 1953 and ended in December 1954. The area surveyed began from Homs, where the demonstration center was installed, and extended north-west to include the Governorates of Hama, Aleppo, and Lattakia up to the Turkish frontiers to the north. The survey extended also north-east to include the Governorates of Euphrates and Jesireh up to the frontiers of Iraq to the east and the Turkish frontiers to the north.

DESCRIPTION OF THE AREA

Topography

Syria has a total area of 70.547 sq. miles. It is bounded: to the west, partly by the Mediterranean sea and partly by Lebanon; to the north, by Turkey; to the east, by Iraq, and to the south by Transjordan and Palestine.

To the west, there are two mountain ranges: the Ansariyeh mountains, in the north, which follow in a general direction the Mediterranean coast; and the Ante-Lebanon mountains, in the south, which follow more or less the boundaries between Lebanon and Syria and extends from the Palestine border northward to Homs. To the east and north of the Ansariyeh mountains, up to the frontiers of Iraq and Turkey, the country is more or less flat and is intersepted with numerous rivers and is agricultural. From the Ante-Lebanon mountains to the Iraqi frontiers, there is the vast Syrian desert.

Rivers and lakes

The Euphrates is considered to be the largest river in the area surveyed, and in Syria in general. The Euphrates and its tributaries, Khabur and Balikh, pass through north-eastern Syria through the Governorates of Euphrates and Jesireh. The rest of the rivers are not large streams. One of the largest and most important of these, is the Orontes river known commonly as Nahr-el-Asy. The Orontes is about 250 miles long. It arises from Ain-el-Asy near Ras Baalbek in Lebanon. It flows in a north-eastern direction to the Lake of Homs. This lake is about six miles long and three miles wide. From the lake, the Orontes flows northward. West of Aleppo, it turns abruptly towards the southwest to flow into the Mediterranean sea. To the most of its length, the Orontes flows through a shallow valley.

FIG. 1: Map of Syria.

Along the northern Turkish frontiers, there are large springs at Ras-el-Ain and Ain-Aarous. These form lakes from which streams run southwards.

On the coast, there are a number of swampy areas, important of which is Nahr-es-Sinn swamp, about twenty miles south of Lattakia. This swamp is about two to three miles long and half a mile wide. There are also several inland swamps, the largest of which is the Ghab, east of the Ansariyeh mountains and south of the town Jisr-el-Chaghour through which the Orontes river winds northwards. The Ghab swamp is about thirty eight miles long and nine miles across. It covers about 100.000 acres and lies 650 feet above sea level. Else than the Ghab, there is a fairly big swamp around the village Tell-Bisseh about ten miles north of Homs city.

The map of Syria (Fig. 1) shows the rivers, lakes, swamps, mountains, important cities, towns and villages in the Governorates surveyed.

Climate

On the coast, the climate is more or less sub-tropical. The dry season lasts from May untill October. The rains begin about the middle of October and last to about the middle of March. During April, there are few showers and from then on there are practically no rains.

The mountains have a temperate climate with winter snows in the higher altitudes. As we proceed from west to east, the heat and dryness increases.

The mean annual rain-fall, temperature and maximum and minimum temperatures for nine important centers within the area surveyed, from September 1953 to August 1954, are given hereunder.

	Rainfall in mms.	Mean temperature in °C.	Maximum temperature in °C. (1)	Minimum temperature in °C. (2)
Homs	791.55	15.32	27.06 (August)	2.23 (December)
Homs	521.50	14.83	27.11 (August)	0.75 (December)
Messiaf	1841.50	15.20	25.91 (August)	3.56 (December)
Aleppo	513.50	17.18	30.17 (August)	3.05 (December)
Jisr-el-Chaghour ...	1038.00	19.66	32.98 (August)	4.33 (December)
Lattakia	766.50	17.42	26.30 (August)	8.18 (December)
Deir-el-Zor	256.70	18.90	32.75 (August)	4.50 (December)
Hassetche	511.50	15.99	31.76 (July)	1.63 (December)
Kamichlieh.....	738.00	16.74	29.00 September	3.30 (February)

(1) Hottest months; (2) Coldest months.

Agriculture

On the dry Orontes plateau, the cheif crops are cereals cultivated without repeated irrigation. Cotton is now much grown in Syria in lands around the rivers Orontes, Euphrates and its tributaries. Sugar beets, melons and other vegetables are much grown around Homs. In the hilly north-west, cereals, tobacco and olives

are raised. Rice is more or less confined to land near the rivers Orontes and El Kabir from which contour canals are led off at frequent intervals. The water is used to innundate the land, most often immediately adjoining the rivers.

PREVIOUS ANOPHELINE RECORDS FROM SYRIA

CHRISTOPHERS (1920), in his observations on the *Anopheles* of the Middle East, recorded *Anopheles sacharovi*, *A. claviger* and *A. superpictus* being the commonest species present in Palestine, Syria and Cilicia. BARRAUD (1921), in his work on Palestine and adjacent countries, took in Syria four species of *Anopheles* (*superpictus*, *sacharovi*, *claviger* and *algeriensis*). LEGENDRE (1924) collected *A. claviger*

TABLE I

List of Anopheles *recorded from Syria and their distribution.*

Governorates	Casas	Number of villages surveyed	*Anopheles* species encountered					
			sacharovi	*superpictus*	*hyrcanus*	*claviger*	*algeriensis*	*pulcherrimus*
Homs	Homs	89	*	*	(-)	*	*	
Hama	Hama	70	*	*	(-)	*		
	Salamia	7		*		*	*	
Lattakia	Banias	8	*	*				
	Tell-Kalakh	35	*	*	(-)			
	Jeble	19	*					
	Haffe	11	*	*	(-)			
	Safita.....	15	*					
	Tartous	7	*	*				
	Lattakia	22	*	*		*		
	Messiaf	9		*				
	Kassab	6	*	*				
Aleppo	Maaret-el-Noman	1	*					
	Membidj	3	*					
	Jisr-el-Chaghour .	13	*	*	(-)			
Euphrate	Deir-el-Zor	2	*	*	*			(-)
	Tell Abiad	6	*	*				(-)
	Sabkha	1		*				(-)
	Mayadine	1		*				(-)
Jesireh	Deirik	10	*	*				(-)
	Kamichlieh.....	8	*	*				(-)
	Hassetche	5	*	*			*	*
	Ras-el-Ain	5	*	*				

(-) = First record from Caza.
* = Previously recorded and newly reported.

from Lattakia. KLIGLER and MER (1936) collected *A. sacharovi*, *A. hyrcanus*, *A. sergenti* and *A. superpictus* from Syria. SAUTET (1941) recorded seven species from Syria and Lebanon (*A. sacharovi*, *A. superpictus*, *A. claviger*, *A. sergenti*, *A. algeriensis*, *A. hyrcanus* and *A. multicolor*). LEESON (1942) recorded *A. marteri* for the first time in Syria. BERBERIAN (1946), in his account of the anophelines in Syria and Lebanon, recorded six species from Syria (*A. superpictus*, *A. sacharovi*, *A. claviger*, *A. hyrcanus*, *A. sergenti* and *A. algeriensis*). The most recent account of the anophelines in Syria was given by LEESON (1950) who encountered all the above species recorded by BERBERIAN with the exception of *A. sergenti*. In addition, LEESON encountered *A. pulcherrimus* once only from north east Syria where larvae were taken from the edge of the Khabour river.

In the present survey, the author encountered the following six *Anopheles* species: *sacharovi*, *superpictus*, *hyrcanus*, *pulcherrimus*, *claviger* and *algeriensis*.

Table I shows the list of *Anopheles* encountered by the author in the six governorates surveyed in Syria, namely Homs, Hama, Lattakia, Aleppo, Euphrates and Jesireh. It is apparent from Table I that first records were established for *A. hyrcanus* and *A. pulcherrimus* and new records were recorded for the rest of the *Anopheles* encountered from the different Cazas of the Governorates surveyed.

Table II shows the results of 594 positive larval and adult collections of the six *Anopheles* species encountered by the author. The figures give the total number of times each species was taken as larvae and as adults, also the number of times the species was taken alone. The anopheline species are listed in Table II in the order of frequency with which they occured in collections.

TABLE II

Frequency of occurrence of Anopheles *larvae and adults encountered between March 1953 and December 1954*

Species	Larvae		Adults		Larvae and adults	Percentage
	Total times taken	Times taken alone	Total times taken	Times taken alone	Total times taken	
sacharovi Favr.	101	57	240	143	341	57.25
superpictus Grassi	48	19	141	51	189	31.81
hyrcanus Pallas	26	3	14	5	40	6.73
pulcherrimus Theobald..	4	—	9	—	13	2.18
claviger Meigen	5	1	4	1	9	1.51
algeriensis Theobald ...	1	—	1	1	2	0.33
Total	185		409		594	99.81

It is apparent from Table II that two species, namely *A. sacharovi* and *A. superpictus* were the most common and abundant anophelines in Syria.

BIOLOGY AND DISTRIBUTION OF THE ANOPHELINE SPECIES ENCOUNTERED IN SYRIA

Anopheles (Anopheles) sacharovi Favr. (elutus Edwards)

This species was considered by CHRISTOPHERS (1920) as one of the commonest in the Middle East. BARRAUD (1921), in his work on Palestine and adjacent countries collected its larvae from marshy ground and rice fields in northern Syria. KLIGLER and MER (1936) collected larvae from Wadi Jeble (Lattakia), from the extensive marsh, the Ghab, south of Jisr-el-Chaghour (Aleppo), also from stagnant small side irrigation channels and the overflow from these channels comming from Lake Homs.

BERBERIAN (1946) considered *Anopheles sacharovi* the principal vector of Malaria and by far the most common anopheline in Syria. He encountered it in the plains crossed by the Orontes and Euphrates rivers and their tributaries where river water was diverted for irrigation purposes and was not properly used.

LEESON (1950) encountered its larvae in Syria in large and small collections of water which were usually covered with horizontal floating aquatic vegetation Larvae were also found in water-storage tanks which had been neglected for so long that their condition had become like that of the natural breeding places. Adult *A. sacharovi* was never observed by LEESON to feed outside human habitations and stables.

In the present survey, *Anopheles sacharovi* was found to be the most dominant anopheline species encountered in Syria. It formed 57.25% of the total times the larvae and adults taken (see Table II).

Larvae of *A. sacharovi* were taken by the author from 101 breeding places including sunny large pieces of stagnant non-brackish waters of marshes, semi-stagnant waters on the banks of marshy rivers and lakes, neglected irrigation canals with emergent and floating vegetation. Rice fields were also found to be favoured by this species.

Larvae were encountered usually in the stagnant waters of marshes exposed to the sun for the greater part of the day, being without closely-overhanging or much emergent vegetation, with mats of submergent vegetation of various kinds floating algal curd and filamentous algae. Such breeding places were common in Tell Bisseh north of Homs city, also in Moudane and Tell-en-Nebi-Mend south-west of Homs. From these breeding places, larvae of *A. sacharovi* were collected together with those of *A. superpictus*, between April and September 1954.

A. sacharovi larvae were also found breeding in the semi-stagnant waters on the banks of marshy rivers and lakes. These breeding sites were overgrown with a great mixture of sub-aquatic vegetation, emergent herbaceous plants such as

grass, reeds, with patches of floating vegetation. Such breeding places were common along the Homs Lake where larvae were either collected alone (villages Chomaria and Dibbine, July 1953), or were associated with larvae of *A. hyrcanus* and *A. superpictus* (the village Syla, July 1953). Such conditions of breeding places were also encountered in Nahr-es-Sinn swamp on the Mediterranean coast near the mouth of Nahr-es-Sinn about 20 miles south of Lattakia, also in the Ghab which is the largest inland swamp formed by the Orontes river. Larvae of *A. sacharovi* were taken from Nahr-es-Sinn swamp in March 1954 in association with those of *A. superpictus.*

All along the Ghab from its northern limits at Jisr-el-Chaghour in Aleppo, to its southern limits in Hama, *A. sacharovi* larvae were collected alone in huge numbers, in August 1954. It was only in three villages, namely El-Ziara, El-Rasif in the caza of Jisr-el-Chaghour (Aleppo), and in Haret-el-Khatib in the caza of Haffe (Lattakia), where larvae of this species were encountered in association with those of *A. hyrcanus.*

Larvae were also encountered in neglected irrigation canals from rivers in the vast area surveyed. These breeding places had their water surfaces more or less shaded by emergent vegetation in the water, e.g. grasses and reeds, and a variety of floating plants. Such type of breeding places were again encountered in many villages in the cazas of Deirik, Kamichlieh, Hassetche, Deir-el-Zor, Tell Abiad and Ain-el-Arab where larvae of *A. sacharovi* were taken in October 1954 in association with those of *A. superpictus.* It was only in two villages, namely Aarbouch in Hassetche caza (Jesireh) and Souar in Deir-el-Zor caza (Euphrates) where *A. sacharovi* larvae were associated with those of *A. superpictus* and *A. pulcherrimus* (see Table I).

That same type of breeding places was also encountered in many villages along the Orontes river in Homs and Hama governorates where *A. sacharovi* larvae were either taken alone or in association with those of *A. superpictus* between March and October 1954.

Rice fields made much favoured breeding places for *A. sacharovi* of which larvae were taken with those of *A. superpictus* in the village Daddate in the caza of Membidj (Aleppo), in July 1954 and also in Tell Kalakh, on Homs-Tripoli road, in August and September 1953. In the latter locality, larvae of *A. sacharovi* were encountered alone.

It is important to note here, that the water of the different breeding places in which *A. sacharovi* was found, was fresh.

Adults of *A. sacharovi* frequented human habitations, animal houses and stables in towns and villages. Adults were also caught while resting on the ceilings or roofs of the above haunting sites. Usually, spider webs commonly found hanging from the roofs of stables and composite rooms (where animals and human beings live under the same roof) in most villages, were the preferred resting places for Adults of *A. superpictus* were usually found associated with *sacharovi* in its resting sites. *A. sacharovi* adults were never caught by the author out-of-doors away from

human habitations, animal houses or stables. Adults increased gradually in density from May to October with a peak in October, and declined afterwards. From November until February, females were found inside human habitations and stables in a state of hibernation. Figure 2 shows the distribution of *Anopheles sacharovi* as found in Syria.

FIG. 2: Distribution of *A. sacharovi*.

DISTRIBUTION : Transjordan (LUMSDEN, 1950), Palestine (SHAPIRO, 1944), Iraq and North Persia (MACAN, 1950), and Lebanon (LEESON, 1950).

Anopheles (Anopheles) hyrcanus Pallas

KLIGLER and MER (1936) collected few larvae of this species from the extensive marsh, the Ghab, south of Jisr-el-Caghour, also from stagnant smaller side chanells fed from bigger channels supplied from Homs Lake and in the overflow from these irrigation channels. BERBERIAN (1946) found it breeding in the marshes of Amik

in the Sandjak of Alexanderetta where the larvae prefered the more stagnant parts of the marsh. Few adults were collected occasionally in the huts along the marshes. According to BERBERIAN, adults did not ordinarily enter human habitations and bit man readily at its breeding sites. LEESON (1950) collected but larvae only in August 1942 from irrigation channels and a large lake at Tell Abiad, north-east Syria, near the Turkish frontiers.

In the present survey, the author encountered this species along the Orontes valley from Homs to Aleppo. It formed 6.73% of the total times larvae and adults taken in collections from Syria (see Table II).

The most northerly breeding place found was at Jisr-el-Chagour in Aleppo, where larvae collected in August 1954 in association with those of *A. sacharovi* from a shallow swamp with emergent and floating vegetation at two villages in the

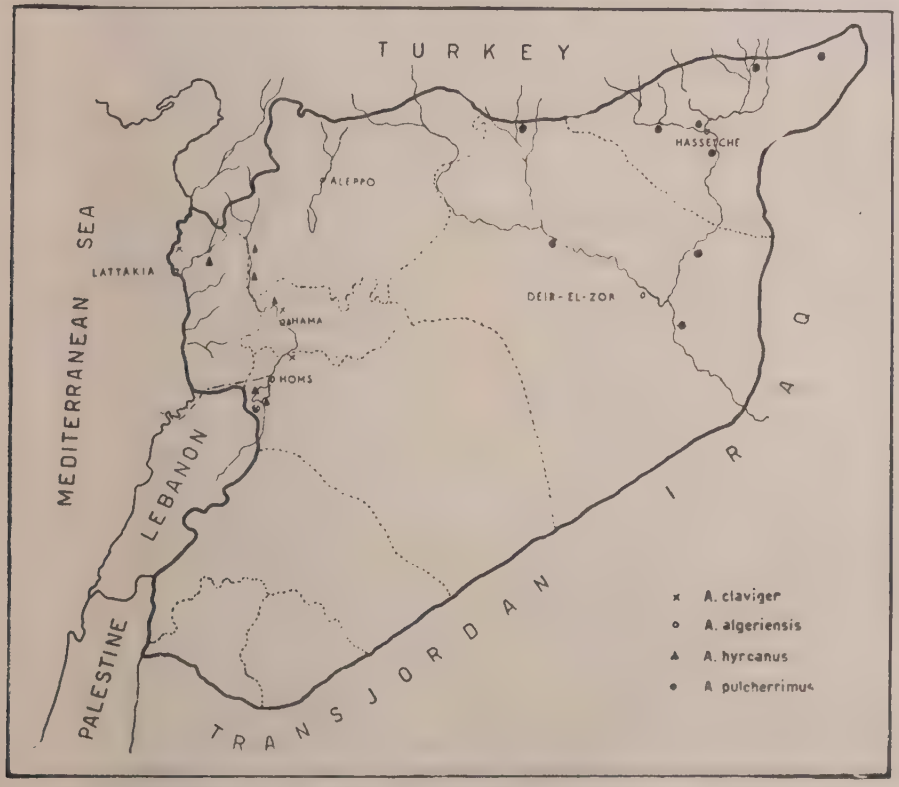

FIG. 3: Distribution of *A. claviger*, *A. algeriensis*, *A. hyrcanus*, and *A. pulcherrimus*.

Ghab, namely El-Ziara and El-Rassif. The most southerly record was at the village Syla on the Homs Lake where larvae were taken in July 53 together with those of *A. superpictus* and *A. sacharovi* from a swamp at the edge of the lake with a great

mixture of subaquatic vegetation, emergent herbaceous plants such as grass and reed with patches of floating algae. Larvae of *A. hyrcanus* were collected alone in October 1953 from a rice field at the village Moudane, south-west of Homs.

Adults of *hyrcanus* were only frequently encoutered inside houses in few numbers. Females were collected in August 1954 together with adults of *A. sacharovi*, while resting on the roof of a composite mud house (where animals and humans live together under the same roof), in two villages in the Ghab south of Jisr-el-Chaghour, namely El Ziara and El Rassif. In February 1954, two females were collected alone while hanging from the roof of a stable in the village Qassarine south-east of Hama town.

Adults were noticed to attack man and domestic animals viciously in and by swamps at nightfall and also at daybreak. Females were collected in enormous numbers on 9th October 1953 while attempting to bite the author on standing at dusk and dawn at the margin of a swamp in the village Moudane west of Homs. Occasional outdoor bitings were recorded by day during the sunny hours.

Figure 3 hows the distribution of this species as found in Syria.

DISTRIBUTION : Syria, Lebanon, Iraq, Transjordan and Palestine. This species was found also in Arabia (LEESON, 1948).

Anopheles (Anopheles) claviger Meigen (bifurcatus) Meigen

This species was reported by BARRAUD (1921) as the most abundant and domestic anopheline mosquito in Syria, breeding almost exclusively in basement rain-water cisterns and covered surface wells. He encountered its larvae once, breeding out-of-doors in a small gently-flowing stream containing much vegetation and overgrown with bushes. SAUTET (1941) also recorded it from Syria, breeding both in cisterns and out-of-doors. BERBERIAN (1946) encountered it breeding in wells in Aleppo and Hama and in most instances adults were found in natural or artificial shelters close to the breeding places. LEESON (1950) took larvae and adults from the numerous wells, underground water cisterns and tombs in Homs and west of Aleppo. In north Aleppo, larvae were found mainly in small springs in the grass and in shady overgrown ditches.

In the present survey, this species formed 1.51 % of the total times larvae and adults taken in collections from Syria (Table II).

The author collected larvae of this species from five breeding sites, including a well, shady irrigation canals with algal floatage, a shady reed swamp supplied from a spring and a shallow hilly ditch containing clear water and algal floatage.

In February 1954, larvae of *A. claviger* were collected alone from a shallow uncovered well situated inside a house in a hilly village called Slayeb north of Lattakia.

In May 1954, larvae were encountered alone in a shady irrigation canal with algal floatage in the village Belouze south-west of Homs. In June 1954, larvae were collected in association with those of *A. algeriensis* from a shady swamp with emergent reeds and agal floatage. This swamp was supplied from a spring known as

Moyanne south of the village Belouze. In November 1953, larvae were taken in association with those of *A. superpictus* from a shallow ditch containing clear water and algal floatage. The ditch was on a hill in the village Rastan north of Homs and was supplied from a spring.

Adults of *A. claviger* were also encountered in different sites. In January 1954, females were collected alone from an underground rocky cave used as a stable in the village Qoumhane north-west of the city of Hama. In February 1954, females were collected together with *A. superpictus* females while resting on spider webs hanging from the roof of a stable in the village Slayeb north of Lattakia. In November 1953, females were taken together with *A. superpictus* from a cave on a hill in Rastan which stands on the banks of the Orontes north of Homs. Females came to bite the author at 11 a.m. while collecting from the above cave in Rastan.

Figure 3 shows the distribution of this species as found in Syria.

DISTRIBUTION : Syria, Lebanon, Iraq, Persia, Palestine and Transjordan.

Anopheles (Anopheles) algeriensis Theobald

BERBERIAN (1946) found larvae of this species breeding in large bodies of stagnant water in Salamia near Hama, in association with larvae of *A. hyrcanus* and occasionally with those of *A. sergenti*. Adults were caught in tents and houses situated near the marshes. LEESON (1950) collected larvae of *algeriensis* from seepage among standing vegetation at Harem on the Turkish frontiers of Syria. He also collected them from a swamp at Rashidiye on the Khabur south of Hassetche, in association with larvae of *A. sacharovi* and *A. superpictus*.

In the present survey, this species formed 0.33% of the total times larvae and adults taken in collections from Syria (Table II).

A. algeriensis was taken only once from Syria. Its larvae were collected by the author with those of *A. claviger* in June 1954, from a reed swamp supplied from Moyanne spring near the village Belouze in the Orontes plateau south-west of Homs. The only adult taken was a single female which came to bite the author while looking for the larvae in the swamp near Moyanne Spring. That was in June 1954. Repeated searches in buildings and shelters of all kinds failed to discover any other adults.

DISTRIBUTION : Egypt (SALEM, 1933), Lebanon, Syria, Palestine, Transjordan and Iraq.

In addition to the six anopheline species collected by the author, two more species were recorded by other authors from Syria. These were *Anopheles marteri* (LEESON, 1942) and *Anopheles sergenti* (BERBERIAN, 1946). So there exist eight anopheline species so far recorded from Syria.

Anopheles (Myzomyia) superpictus Grassi

CHRISTOPHERS (1920) found this species common in the Middle East. BARRAUD (1921) took it from Syria between May and October. KLIGLER and MER (1936)

collected its larvae in Syria from concrete channels used for drainage where the flow was sluggish with an overgrowth of algae and also from winding and narrow streams covered with vegetation. Large numbers were found in the bedouin's huts. BERBERIAN (1946) encountered larvae in different breeding sites including sunny mountain streams, mountain springs, man-made ditches and in irrigation canals in which the stream is slowed down with floating debris and covered with bushes. LEESON (1950) found larvae common in streams with pebbly beds, near the edges, among the stones. They were also found in sand pits, in wells dug in river beds, in irrigation tanks and in the leakage from these. Breeding places were usually exposed to sunshine. According to LEESON, during the summer adults frequented human habitations, animal houses, stables and chicken sheds and were found out-of-doors near such places and also miles away from human habitations in crevices in the earth, near rivers, in railway tunnels and under bridges.

In the present survey, *Anopheles superpictus* was found to come next to *A. sacharovi* as far as frequency of occurence in Syria is concerned. This species formed 31.8% of the total times larvae and adults taken in collections (see Table II).

Larvae of *A. superpictus* were taken from 48 breeding places including well-lit sunny surface-running waters among the pebbles with or without green algal growth, neglected irrigation canals with emergent and horizontal vegetation, rice fields and open parts of swamps. Larvae were also encountered in small collections in hoof prints.

Larvae were also collected during August and September 1953 from slow moving well-lit sunny mountain streams of clear water running among pebbles with no green algal growth. Such breeding sites were available in the villages Ain-Haramia, Bahlounia, Qraiyat, Ozeir, Tell Serin, Mahtabia and Cheboc, all of which belong to Tell-Kalakh caza (Lattakia) and are situated south of the Homs-Tripoli road, south-west of Tell-Kalakh town.

In November 1953, larvae of *superpictus* were collected in Rastan, north of Homs city, from a shallow well-lit pit situated on a hill and containing clear water with green algal floatage. The larvae were in association with those of *A. claviger*.

Neglected irrigation canals with emergent and horizontal vegetation which slow down the water stream, seem to be the most favoured breeding places of *A. superpictus* in Syria. Larvae were collected in October 1954, either alone or in association with those of *A. sacharovi*, from such breeding sites present in many villages in the cazas of Derik, Kamichlieh, Hassetche, Deir-el-Zor, Tell Abiad and Ain-el-Arab. In only two villages, namely Aarbouch in Hassetche caza (Jesireh) and Souar in Deir-el-Zor caza (Euphrates), larvae of *superpictus* were found in association with those of both *A. sacharovi* and *A. pulcherrimus*. Larvae of *A. superpictus* were also collected in association with those of *A. pulcherrimus* only from the villages Sabba-Sokoor and Moujarjah near Hassetche on the Khabour river. The same type of breeding places were also encountered in many other villages along the

Orontes river in Homs and Hama governorates where larvae of *A. superpictus* were taken in association with those of *A. sacharovi* between March and October 1954.

Larvae of *superpictus* were caught, in association with those of *A. sacharovi* in July 1954, from rice fields in the village Daddate in the caza of Membidj (Aleppo). Larvae were also collected in March 1954 from the edge of Nahr-el-Sinn swamp south of Lattakia in association with those of *A. sacharovi*.

In July 1953, larvae of *superpictus* were collected, together with those of *A. sacharovi* and *A. hyrcanus*, from semi-stagnant waters along the Homs Lake in the village Syla west of Homs.

Hoof prints with clear water were found, in August 1954, to contain larvae of *superpictus* in the village Ichtebraq south of Jisr-el-Chaghour (Aleppo).

Adults of *A. superpictus* were found to frequent the same resting and haunting sites of *A. sacharovi*., which include human habitations, animal houses and stables where they shelter in dark corners, spider webs, behind clothes and untensils hanging on the walls, under tables or inside the huge earthenware containers used by villagers

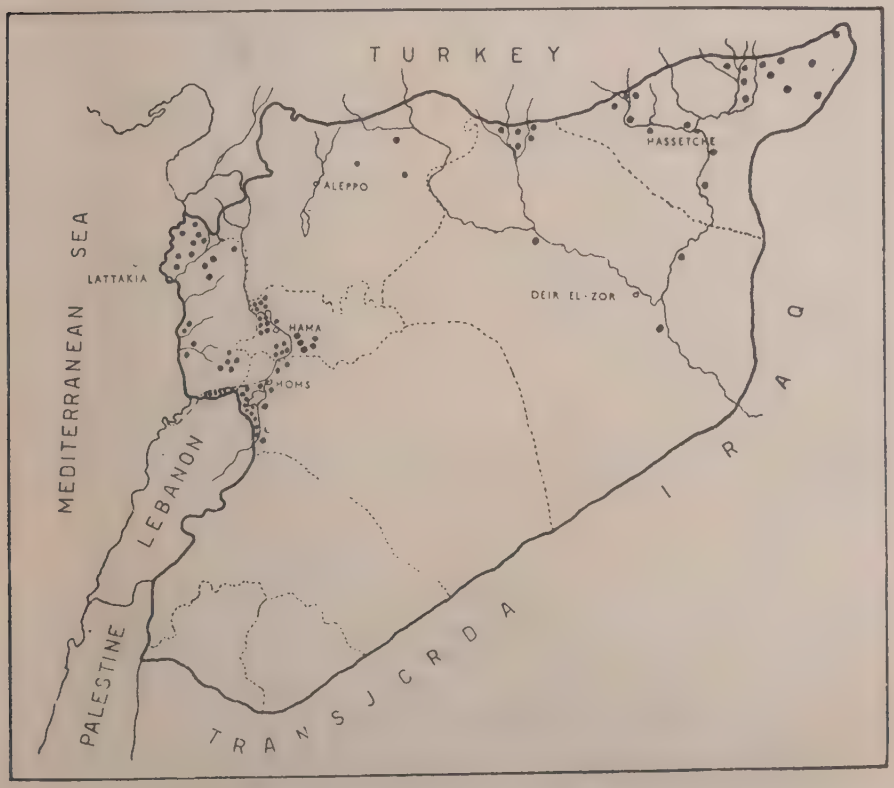

FIG. 4: Distribution of *A. superpictus*.

for storage of cereals. In addition, *A. superpictus* adults were caught out-of-doors away from human habitations. In November 1953, adults were caught together with *A. claviger* from caves in Rastan north of Homs. Also the rocky caves present around Hama were found to be favoured resting sites for adults of *superpictus*.

As with *A. sacharovi*, adults of *superpictus* increased gradually in density from May to October, with a peak in October, and started to decline until March. when females were found in human habitations and stables in a state of hibernation

Figure 4 shows the distribution of this species as found in Syria.

DISTRIBUTION: Egypt (KIRKPATRICK, 1925, ABDEL-MALEK, 1956), Syria and Lebanon (LEESON, 1950), Transjordan (LUMSDEN, 1950), Palestine (SHAPERO, 1944), Iraq and North Persia (MACAN, 1950), and Arabia (BUXTON, 1944).

Anopheles (Myzomyia) pulcherrimus Theobald

CHRISTOPHERS (1920), in his observations upon the *Anopheles* of the Middle East, remarked that the Syrian and Arabian deserts seem to form the western limit of distribution *A. pulcherrimus*. LEESON (1950) took it once only from Syria, in August 1942, when larvae were collected with those of *A. superpictus* from the edge of the Khabur river in north-east Syria near the village of Khoura outside Hassetche on the road to Ras-el-Ain. No adults were ever taken by LEESON inspite of special repeated searches.

In the present survey, this species formed 2.18% of the total times larvae and adults taken in collections from Syria (see Table II).

The author collected both larvae and adults of *pulcherrimus* in the later part of October 1954 from different sites in Jesireh and Euphrates governorates. In the Jesireh governorate, larvae were taken with those of *A. sacharovi* and *A. superpictus* from shallow pools, with emergent and floating vegetation, formed by overflow of irrigation canals comming from the Khabur river in three villages situated on the same river, namely Aarbouch, near Tell Tamer north-west of Hassetche city, and Moujarjah and Sabaa Sokoor north and south of Hassetche, respectively.

In the Euphrates governorate, larvae of *A. pulcherrimus* were taken with those of *A. sacharovi* and *A. superpictus* from the edge of an irrigation canal with emergent vegetation and scattered floating algae, in the village Souar on the Khabur river north-east of Deir-el-Zor city.

Adults of *pulcherrimus* were taken nine times during October 1954. In all occasions, adults were caught while resting on the spider webs hanging from the roofs of the mud houses and stables made out of reed and tree branches.

In the governorate of Jesireh, adults of *A. pulcherrimus* were taken from a sleeping room on October 14 th in the village Tell Hadi near Deirik close to the Turkish and Iraqi frontiers, from a composite room on October 17th together with *A. sacharovi* and *A. superpictus* in the village Tell Barham near Qoubour-el-Bid south-east of Kamichlieh, from a stable on October 20th with *A. sacharovi* and *A. superpictus* in the village Aarbouch near Tell-Tamer north-west of Hassetche

on the Khabur river, and from sleeping rooms and stables on October 21st with *A. sacharovi* and *A. superpictus* in the villages Saba-Sokoor and Moujarjah near Hassetche on the Khabur river.

In the Euphrates governorate, adults were taken from a stable on October 25th together with *A. sacharovi* and *A. superpictus* in the village Souar north-west of Deir-el-Zor on the Khabur river, from a stable on October 23rd with *A. superpictus* in the village Roeha near Bseira north of Mayadine town on the Euphrates river, from a sleeping hut made out of reed mats in the village Shreida near Sabkha town on the Euphrates river south-east of Rakka town, and from as leeping room on October 28th in the village Al-Monbatih near Tell Abiad on the Turkish frontier.

Figure 3 shows the distribution of this species as found in Syria.

DISTRIBUTION: Arabia (BUXTON, 1944), Iraq and Persia.

Key to the adults species of *Anopheles* recorded from Syria

1. Costal margin with four or more distinct pale spots 6
   Costal margin with less than four distinct pale spots 2
2. Wing scales bi-colorous ..... **hyrcanus**
   Wing scales of uniform dark colour 3
3. Wing scales clumped to form spots in the middle of wing ..... **sacharovi**
   Wing scales uniformly distributed with no dark spots 4
4. Mesonotum with golden hairs or scales on the median area and with tuft of pale scales on anterior border ..... **claviger**
   Mesonotum with dark hairs only and no scales 5
5. Vertex with tuft of pale scales, apex of wing with pale fringe scales .... **marteri**
   Vertex with no tuft of pale scales, apex of wing with dark fringe scales ..... **algeriensis**
6. Hind tarsi white ..... **pulcherrimus**
   Hind tarsi dark 7
7. Mesonotum with hairs and scales; base of costa pale ..... **superpictus**
   Mesonotum with hairs but no scales; base of costa dark ..... **sergenti**

Key to the fourth stage larva of the *Anopheles* species recorded from Syria

1. Inner clypeal hairs approximate, much closer to one another than they are to the outer clypeals ..... **(Anopheles)** 2
   Inner clypeal hairs widely seperated. as far apart as they are from the outer clypeals ..... **(Myzomyia)** 6
2. Outer clypeal hairs thickly branched into a fan-like structure 3
   Outer clypeal hairs simple or very slightly branched 4

3. Antennal hair branched, arising near middle of antenna, inner clypeal hairs usually simple ..... **hyrcanus**
   Antennal hair branched, arising at the basal fourth of antenna; inner clypeal hairs branched at tip ..... **sacharovi**
4. Leaflets of abdominal palmate hairs abruptly narrowed before apex .... **marteri**
   Leaflets of abdominal palmate hairs uniformly tapernig to apex 5
5. Fronto-clypeal markings consisting of seperate spots; base of saddle hair at edge or just off saddle ..... **claviger**
   Fronto-clypeal markings forming a dark transverse band; base of saddle hair within margin of saddle ..... **algeriensis**
6. Outer clypeal hairs simple 7
   Outer clypeal hairs branched ..... **pulcherrimus**
7. One of the long metapleural bristles simple; three accessory tergal plates present on the dorsum of the abdominal segments ..... **sergenti**
   Both long metapleural bristles feathered; only one accessory tergal plate present on the dorsum of the abdominal segments..... **superpictus**

SUMMARY

A survey for the study of the distribution and biology of the *Anopheles* species present in Syria north of Homs Governorate up to the Mediterranean coast to the west, the Turkish frontiers to the north and the Iraqi boundaries to the east, is the basis of this paper. New records of distribution and biological notes are given for the larvae and adults of the six *Anopheles* species encountered, namely *A. sacharovi*, *A. superpictus*, *A. hyrcanus*, *A. pulcherrimus*, *A. claviger* and *A. algeriensis*. Adults of*A. pulcherrimus* were encountered in Syria for the first time. Simple keys for the identification of the anopheline adults and larvae so far recorded from Syria are devised.

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السنة الحادية والخمسون

مجلة الجمعية المصرية لعلم الحشرات

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